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Vol. I

TRANSCRIPT OF RECORD

Supreme Court of the United States

OCTOBER TERM, 1938

No. 127

MACKAY RADIO AND TELEGRAPH COMPANY, INC.,
PETITIONER,

vs.

RADIO CORPORATION OF AMERICA

ON WRIT OF CERTIORARI TO THE UNITED STATES CIRCUIT COURT
OF APPEALS FOR THE SECOND CIRCUIT

PETITION FOR CERTIORARI FILED [illegible], 1938.

CERTIORARI GRANTED [illegible], 1938.

SUPREME COURT OF THE UNITED STATES

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VOL. I

INDEX.

JUDD & DETWEILER (INC.), PRINTERS, WASHINGTON, D. C., NOVEMBER 7, 1938.

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[fol. 1]

IN UNITED STATES DISTRICT COURT, EASTERN DISTRICT OF NEW YORK

In Equity. No. 7234

RADIO CORPORATION OF AMERICA, Plaintiff,

vs.

MACKAY RADIO AND TELEGRAPH COMPANY, INC., Defendant

On Carter Patents Nos. 1,623,996 and 1,909,610, and Lindenblad Patents Nos. 1,884,006 and 1,927,522

BILL OF COMPLAINT

To the Honorable the Judges of the United States District Court for the Eastern District of New York:

The plaintiff, by this, its bill of complaint, alleges as follows:

1. That the plaintiff, Radio Corporation of America, is a corporation duly organized and existing under and by virtue of the laws of the State of Delaware; and, upon information and belief, that the defendant, Mackay Radio and Telegraph Company, Inc., is a corporation duly organized and existing under and by virtue of the laws of the State of Delaware, and that it has a regular and established place of business in the County of Suffolk, State of New York, in the Eastern District of New York, and has committed, is now committing, and threatens to continue to commit acts of infringement of each of the Letters Patent here in suit within said Eastern District of New York.

[fol. 2] 2. That this is a suit in equity arising under the Patent Laws of the United States for the infringement by the defendant of the following United States Letters Patent, viz:

Inventor	Patent No.	Date of Grant
Philip S. Carter	1,623,996	April 12, 1927.
Nils E. Lindenblad	1,884,006	October 25, 1932.
Nils E. Lindenblad	1,927,522	September 19, 1933.
Philip Staats Carter	1,909,610	May 16, 1933.

3. Upon information and belief, that Philip S. Carter, being the first, true, original, and sole inventor or discoverer of certain new and useful improvements in a "Radio Transmission System", not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, or more than two years prior to his application for Letters Patent in the United States, next hereinafter mentioned, and not in public use or on sale in this country for more than two years prior to the date of his said application, and not abandoned, and not patented or caused to be patented by him or his legal representatives or assigns in any country foreign to the United States on any application filed more than twelve months prior to his said application, and being then the owner of the entire right, title and interest in and to said invention or discovery and improvements, did, on or about June 12, 1923, by an instrument in writing, duly executed and delivered on or about said day, and recorded in the United States Patent Office June 25, 1923, duly sell and assign to the plaintiff, Radio Corporation of America, its successor and assigns, the said improvements, [fol. 3] and the next hereinafter mentioned application for Letters Patent of the United States therefor and all Letters Patent which might be granted therefor, and authorized and requested the Commissioner of Patents to issue such Letters Patent to the plaintiff as the assignee of the entire interest.

4. That on or about June 25, 1923, an application in writing for the grant of Letters Patent upon said invention or discovery and improvements was duly made and filed with the Commissioner of Patents of the United States on behalf of said Philip S. Carter.

5. That on or about February 12, 1925 an application in writing was duly made and filed with the Commissioner of Patents of the United States renewing the application referred to in paragraph 4 hereof, the invention thereof not having been abandoned.

6. That Letters Patent numbered 1,623,996 were, on April 12, 1927, duly issued upon the aforesaid application filed June 25, 1923, as renewed by said application filed February 12, 1925, all the provisions and requirements of the statutes of the United States in such cases made and provided hav-

ing been duly complied with, said patent being issued to the plaintiff, Radio Corporation of America, its successors and assigns, whereby there was granted to it and them for the term of seventeen years from the date thereof, the exclusive right to make, use and vend the invention or discovery and improvements set forth, described and claimed therein, throughout the United States and the Territories thereof.

[fol. 4] 7. Upon information and belief, that Nils E. Lindenblad, being the first, true, original, and sole inventor or discoverer of certain new and useful improvements in an "Antenna", not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, or more than two years prior to his application for Letters Patent in the United States, next hereinafter mentioned, and not in public use or on sale in this country for more than two years prior to the date of his said application, and not abandoned, and not patented or caused to be patented by him or his legal representatives or assigns in any country foreign to the United States on any application filed more than twelve months prior to his said application, and being then the owner of the entire right, title and interest in and to said invention or discovery and improvements, did, on or about August 31, 1928, by an instrument in writing, duly executed and delivered on or about said day, and recorded in the United States Patent Office September 7, 1928, duly sell and assign to the plaintiff, Radio Corporation of America, its successors and assigns, the said improvements, and the next hereinafter mentioned application for Letters Patent of the United States, and all Letters Patent which might be granted therefor, and authorized and requested the Commissioner of Patents to issue such Letters Patent to the plaintiff as the assignee of the entire interest.

8. That on or about September 7, 1928, an application in writing for the grant of Letters Patent upon said invention [fol. 5] or discovery and improvements was duly made and filed with the Commissioner of Patents of the United States on behalf of said Nils E. Lindenblad.

9. That Letters Patent numbered 1,884,006 were, on October 25, 1932, duly issued upon the aforesaid application

filed September 7, 1928, all the provisions and requirements of the statutes of the United States in such cases made and provided having been duly complied with, said patent being issued to the plaintiff, Radio Corporation of America, its successors and assigns, whereby there was granted to it and them for the term of seventeen years from the date thereof, the exclusive right to make, use and vend the invention or discovery and improvements set forth, described and claimed therein, throughout the United States and the Territories thereof.

10. Upon information and belief, that Nils E. Lindenblad, being the first, true, original, and sole inventor or discoverer of certain new and useful improvements in an "Antenna for Radio Communication", not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, or more than two years prior to his application for Letters Patent in the United States next hereinafter mentioned, and not in public use or on sale in this country for more than two years prior to the date of his said application, and not abandoned, and not patented or caused to be patented by him or his legal representatives or [fol. 6] assigns in any country foreign to the United States on any application filed more than twelve months prior to his said application, and being then the owner of the entire right, title and interest in and to said invention or discovery and improvements, did, on or about December 17, 1928, by an instrument in writing, duly executed and delivered on or about said day, and recorded in the United States Patent Office December 24, 1928, duly sell and assign to the plaintiff, Radio Corporation of America, its successors and assigns, the said improvements, and the next hereinafter mentioned application for Letters Patent of the United States and all Letters Patent which might be granted therefor, and authorized and requested the Commissioner of Patents to issue such Letters Patent to the plaintiff as the assignee of the entire interest.

11. That on or about December 24, 1928, an application in writing for the grant of Letters Patent upon said invention or discovery and improvements was duly made and filed with the Commissioner of Patents of the United States on behalf of said Nils E. Lindenblad.

12. That Letters Patent numbered 1,927,522 were, on September 19, 1933, duly issued upon the aforesaid application filed December 24, 1928, all the provisions and requirements of the statutes of the United States in such cases made and provided having been duly complied with, said patent being issued to the plaintiff, Radio Corporation of America, its successors and assigns, whereby there was granted to it and them for the term of seventeen years from the date thereof, the exclusive right to make, use and vend the invention or [fol. 7] discovery and improvements set forth, described and claimed therein, throughout the United States and the Territories thereof.

13. Upon information and belief, that Philip Staats Carter, being the first, true, original, and sole inventor or discoverer of certain new and useful improvements in an "Electric Circuit", not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, or more than two years prior to his application for Letters Patent in the United States, next hereinafter mentioned, and not in public use or on sale in this country for more than two years prior to the date of his said application, and not abandoned, and not patented or caused to be patented by him or his legal representatives or assigns in any country foreign to the United States on any application filed more than twelve months prior to his said application, and being then the owner of the entire right, title and interest in and to said invention or discovery and improvements, did, on or about March 6, 1930, by an instrument in writing, duly executed and delivered on or about said day, and recorded in the United States Patent Office March 12, 1930, duly sell and assign to the plaintiff, Radio Corporation of America, its successors and assigns, the said improvements, and the next hereinafter mentioned application for Letters Patent of the United States and all Letters Patent which might be granted therefor, and authorized and requested the Commissioner of Patents to issue such Letters Patent to the plaintiff as assignee of the entire interest.

[fol. 8] 14. That on or about March 12, 1930, an application in writing for the grant of Letters Patent upon said invention or discovery and improvements was duly made and

filed with the Commissioner of Patents of the United States on behalf of said Philip Staats Carter.

15. That Letters Patent numbered 1,909,610 were, on May 16, 1933, duly issued upon the aforesaid application filed March 12, 1930, all the provisions and requirements of the statutes of the United States in such cases made and provided having been duly complied with, said patent being issued to the plaintiff, Radio Corporation of America, its successors and assigns, whereby there was granted to it and them for the term of seventeen years from the date thereof, the exclusive right to make, use and vend the invention or discovery and improvements set forth, described and claimed therein throughout the United States and the Territories thereof.

16. That the plaintiff has been ever since the grant of each of said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522 and 1,909,610, respectively, and now is, the sole and exclusive owner of each of them and of all claims for profits and damages for past infringement thereof.

17. That the plaintiff asks that the aforesaid assignments and Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522, and 1,909,610, be deemed and taken as a part of this bill of complaint, and asks leave to refer to the originals of the same or duly authenticated copies thereof, now in their possession and ready in Court to be produced.

[fol. 9] 18. That the plaintiff and one or more of its licensees have expended large sums of money in making the inventions, discoveries and improvements of said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522 and 1,909,610, useful to the public and themselves; that the same have been practiced, and are now being practiced, by one or more of the licensees of the plaintiff; that the same have been and are of great value, importance, benefit and advantage to the plaintiff and its licensees and to the public; and that the same are capable of conjoint use, in one and the same structure and system, and have been and are being so used by the defendant.

19. That prior to the commencement of this suit, the defendant was duly notified of its infringement of said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522, and 1,909,610, and of each of them, and, as plaintiff is informed and be-

lieves, the defendant continued, after such notice, to use the inventions of each of said Letters Patent.

20. Upon information and belief, that since the dates of issuance of said Letters Patent Ncs. 1,623,996, 1,884,006, 1,927,522 and 1,909,610, respectively, and within six years last past, and without right, license or consent of the plaintiff, and within the Eastern District of New York and elsewhere within the United States, the defendant, Mackay Radio & Telegraph Company, Inc., has made, installed, used and caused to be used devices, apparatus, structures, methods, and systems embodying and employing the respective inventions, discoveries, and improvements of each of said Letters Patent and infringement of each of them, and [fol. 10] also material and substantial parts of the inventions, discoveries and improvements of each of said Letters Patent, and now is continuing and threatening to continue to commit said acts of infringement.

21. Upon information and belief, that the defendant has derived and received and will derive and receive from the aforesaid infringement gains, profits, and advantages, but to what amount the plaintiff is not informed and cannot set forth; that the plaintiff and its licensees, by reason of the said infringement by the defendant, have been and will be deprived of and prevented from receiving, if such infringement is not restrained by this Court, gains, profits and advantages to which the plaintiff and its licensees are lawfully entitled and which they would have derived and received and would now be deriving and receiving but for the aforementioned infringement; that by reason of the aforesaid infringement the plaintiff and its licensees have been irreparably injured and have sustained losses and damages thereby; that the said infringement by the defendant has had and will have the effect of encouraging and inducing others to venture to infringe upon said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522, and 1,909,610, and each of them; and that, unless the said infringement by the defendant is enjoined by this Court, further irreparable injury, loss and damage will be caused to the plaintiff and its licensees.

The plaintiff therefore prays:

I. That the defendant, Mackay Radio & Telegraph Company, Inc., and its directors, officers, associates, attorneys,

[fol. 11] clerks, servants, agents, workmen and employees, be perpetually enjoined and restrained by a decree of this Court from directly or indirectly making or causing to be made, using or causing to be used, leasing or causing to be leased, selling or causing to be sold, advertising or offering for sale, use and lease, or causing to be advertised or offered for sale, use and lease, agreeing or contracting to sell and lease, causing to be agreed or contracted for sale and lease, supplying or causing to be supplied, installing or causing to be installed, threatening to offer or contract for sale, lease, and supply, or disposing of in any manner, devices, instruments, appliances, apparatus, structures, methods, or systems employing or employing the respective inventions or discoveries or improvements of said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522, and 1,909,610, or of any of them, or any substantial, material, or vital part or parts of said Letters Patent or of any of them, and from infringing upon or contributing to the infringement of, or encouraging, inducing or aiding the infringement of said Letters Patent or of any of them in any way whatsoever.

II. That a preliminary injunction issue against said defendant to the same tenor and effect as hereinbefore prayed for in respect to said perpetual injunction.

III. That said defendant be decreed to account to the plaintiff for all such gains, profits and advantages as have accrued to or have been earned or received by said defendant and also for all damages the plaintiff has sustained by [fol. 12] said infringement, and that the Court assess the same, or cause them to be assessed under its direction and increase the same as provided by law.

IV. That the said defendant be decreed to pay the costs, charges, and disbursements of this suit, and that the plaintiff have such other and further relief as the premises and the equity of the case may require and to the Court may seem just.

Radio Corporation of America, by Otto S. Schairer, Its Vice-President. Sheffield & Betts, Solicitors for Plaintiff. Abel E. Blackmar, Jr., Of Counsel for Plaintiff.

[fol. 13] *Duly sworn to by Otto S. Schairer. Jurat omitted in printing.*

[fol. 14] IN UNITED STATES DISTRICT COURT, EASTERN DISTRICT OF NEW YORK

[Title omitted]

ANSWER

The defendant, for answer to the bill of complaint herein, or to as much thereof as it is advised is necessary or material to be answered, on information and belief says:

1. Answering paragraph 1 of the bill of complaint defendant denies that it has infringed the patents involved in the suit in the Eastern District of New York or elsewhere.

2. Defendant denies each and every allegation contained in paragraphs 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 of the bill of complaint, except that it admits having seen what purported to be printed copies of Carter patents Nos. 1,623, 999 and 1,909,610, and Lindenblad patents Nos. 1,884-006 and 1,927,522 granted on the dates appearing thereon on applications filed on the dates recited therein.

3. For answer to paragraph 16 of the bill of complaint defendant is without information, save that obtained from the [fol. 15] bill of complaint, and from the said printed copies of the said patents, and therefore leaves plaintiff to its proofs.

4. Defendant denies each and every allegation contained in paragraphs 18, 19, 20, and 21 of the bill of complaint.

5. Further answering the bill of complaint, defendant affirmatively asserts that it does not infringe said Letters Patent or anyone thereof.

6. Further answering the bill of complaint defendant asserts that the said Letters Patent, and each thereof, are wholly void and invalid at law for each of the following reasons, to wit:

(a) Because the alleged invention of said Letters Patent, and each thereof, was shown and/or described in printed publications of the United States and countries foreign to the United States before the alleged invention by the respective patentees, and more than two years prior to the

filing of application for patent on which said respective patents issued, as follows:

(1) As to Carter Patent No. 1,623,996—

United States Patents

No.	Inventor	Issue Date
712,766	Colpitts	Nov. 4, 1902
729,709	Warren-Campbell	June 21, 1903
730,246	DeForest	June 9, 1903
730,247	DeForest	June 9, 1903
730,819	DeForest	June 9, 1903
773,472	Campbell	Oct. 25, 1904
874,411	LeBlanc	Dec. 24, 1907
956,165	Pickard	Apr. 26, 1910
961,265	Stone	June 14, 1910
1,013,456	Seibt	Dec. 19, 1911

[fol. 16]

No.	Inventor	Issue Date
1,124,904	Hoyt	Jan. 12, 1915
1,129,959	Colpitts	Mar. 2, 1915
1,167,693	Hoyt	Jan. 11, 1916
1,219,760	Mills-Hoyt	Mar. 20, 1917
1,243,066	Hoyt	Oct. 16, 1917
1,301,644	Buckley	Apr. 22, 1919
1,313,483	Heising	Aug. 19, 1919
1,322,634	Shaw	Nov. 25, 1919
1,333,111	Hoyt	Mar. 9, 1920
1,367,590	Demarest	Feb. 8, 1921
1,381,089	Beverage	June 7, 1921
1,430,808	Hoyt	Oct. 3, 1922
1,452,849	Round	Apr. 24, 1923

British Patent

4277/1873

Publications

Electrical Papers, Vol. 2, by Heaviside, pp. 124-155—"Electromagnetic Induction and Its Propagation"; published 1892 by MacMillan Company.

Electrical World & Engineer, Vol. 38, No. 19, November 9, 1901, pp. 775-776—"Slaby-D'Arco Multiple Wireless System".

The Electrical World, Vol. 48, No. 21, November 24, 1906—"The Carborundum Wireless Detector".

Electric Waves, published October, 1909, by MacMillan Company, New York, W. S. Franklin, Chaps. IV and V, pp. 75-153.

Proceedings I. R. E., Vol. 31, Part I, May 17, 1912—"Propagation of Impulses over a Transmission Line" by Cunningham and Davis.

[fol. 17] The Wireless World, Vol. 1, November, 1913—"Electromagnetic Waves Employed in Radio-Telegraphy" by Howe, pp. 486-492.

The Wireless World, Vol. 1, December, 1913—"The Use of High Resistance Telephones", pp. 580-581.

Transactions of A. I. E. E., Vol. 33, April, 1914—"Some Simple Examples of Transmission Line Surges" by W. S. Franklin, pp. 545-569.

(a) As to Carter Patent No. 1,909,610—

United States Patents

No.	Inventor	Issue Date
712,766	Colpitts	Nov. 4, 1902
729,709	Warren-Campbell	June 21, 1903
730,246	DeForest	June 9, 1903
730,247	DeForest	June 9, 1903
730,819	DeForest	June 9, 1903
773,472	Campbell	Oct. 25, 1904
874,411	LeBlanc	Dec. 24, 1907
956,165	Pickard	Apr. 26, 1910
961,265	Stone	June 14, 1910
1,012,456	Seibt	Dec. 19, 1911
1,124,904	Hoyt	Jan. 12, 1915
1,129,959	Colpitts	Mar. 2, 1915
1,167,693	Hoyt	Jan. 11, 1916
1,219,760	Mills-Hoyt	Mar. 20, 1917
1,243,066	Hoyt	Oct. 16, 1917
1,301,644	Buckley	Apr. 22, 1919
1,313,483	Heising	Aug. 19, 1919
1,322,634	Shaw	Nov. 25, 1919
1,333,111	Hoyt	Mar. 9, 1920
1,367,590	Demarest	Feb. 8, 1921
1,381,089	Beverage	June 7, 1921
1,430,808	Hoyt	Oct. 3, 1922
1,452,849	Round	Apr. 24, 1923
1,475,997	Hoyt	Dec. 4, 1923
1,487,308	Beverage	Mar. 18, 1924
1,495,221	Clark	May 27, 1924
1,537,101	Whiting	May 12, 1925

[fol. 18]

No.	Inventor	Issue Date
1,562,961	Heising	Nov. 24, 1925
1,585,018	Casper-Whittle	May 18, 1926
1,601,023	Hoyt	Sept. 28, 1926
1,602,085	Rice-Kellogg	Oct. 5, 1926
1,602,086	Rice-Kellogg	Oct. 5, 1926
1,623,996	Carter	Apr. 12, 1927
1,628,983	Johnson	May 17, 1927
1,647,985	Deutschmann	Nov. 8, 1927
1,676,240	Affel	July 10, 1928
1,689,334	Feldtkeller	Oct. 30, 1928
1,690,233	Kupfmuller	Nov. 6, 1928
1,691,098	Whiting	Nov. 13, 1928

Publications

Electrical Papers, Vol. 2, by Heaviside, pp. 124-155—"Electromagnetic Induction and Its Propagation", published 1892 by MacMillan Company.

Electrical World & Engineer, Vol. 38, No. 19, November 9, 1901, pp. 775-776—"Slaby D'Arco Multiple Wireless System".

The Electrical World, Vol. 48, No. 21, November 24, 1906—"The Carborundum Wireless Detector", by Pickard, pp. 994-995.

Electric Waves, published October, 1909, by MacMillan Co., New York, W. S. Franklin, Chaps. IV and V, pp. 75-153.

Proceedings I. R. E., Vol. 31, Part I, May 17, 1912—"Propagation of Impulses Over a Transmission Line", by Cunningham and Davis.

The Wireless World, Vol. 1, November, 1913—"Electromagnetic Waves Employed in Radio-Telegraphy", by Howe, pp. 486-492.

[fol. 19] The Wireless World, Vol. 1, December, 1913—"The Use of High Resistance Telephones", pp. 580-581.

Transactions of A. I. E. E., Vol. 33, April, 1914—"Some Simple Examples of Transmission Line Surges", by W. S. Franklin, pp. 545-569.

Transmission Circuits for Telephonic Communication, published 1925 by Van Nostrand—K. S. Johnson—Chaps. VII and VIII, pp. 43-85.

British Patents

4277/1873
282905/1927

(3) As to Lindenblad Patent No. 1,884,006—

United States Patents

No.	Inventor	Issue Date
741,622	Brown	Oct. 20, 1903
749,131	DeForest	Jan. 5, 1904
808,594	Artom	Dec. 26, 1905
992,791	McElroy	May 23, 1911
1,020,032	Fessenden	Mar. 12, 1912
1,116,588	Harrison	Nov. 10, 1914
1,360,167	Alexanderson	Nov. 23, 1920
Re-15,040	Franklin	Feb. 15, 1921
Re-15,041	Franklin	Feb. 15, 1921
1,370,735	Franklin	Mar. 8, 1921
1,562,961	Heising	Nov. 24, 1925
1,643,323	Stone	Sept. 27, 1927
1,658,740	Rice	Feb. 7, 1928

British Patents

11,427/1903
233,346/1926
251,638/1927

[fol. 20] French Patents

593,570, Published Aug. 26, 1925;
Add. 30,798, Published Aug. 23, 1926.

Publications

Maxwell's Theory and Wireless Telegraphy, by Poincaré—Vreeland, published 1904, McGraw Pub. Co., p. 94.

The Electrician, December 18, 1914—"The Possibility of Sharp Direction Wireless Telegraphy", by Bellini, pp. 352-354.

Proceedings of Physical Society of London, Vol. 29, 1917—"Radiation from Antennae", by Van der Pol, pp. 269-289.

Proceedings I. R. E., Vol. 12, October, 1924—"On the Optimum Transmitting Wave Length for a Vertical

Antenna Over Perfect Earth", by Stuart Ballantine, pp. 833-839.

"On the Radiation Resistance of a Simple Vertical Antenna at Wavelengths Below the Fundamental", by Stuart Ballantine, pp. 823-832.

Proceedings I. R. E., Vol. 13, April, 1925—Discussion re above, pp. 251-255.

Q. S. T., August, 1926—"Straightening Out the Antenna", by Melton, pp. 30-32.

Proceedings I. R. E., Vol. 14, October, 1926—"Field Distribution and Radiation Resistance of a Straight Vertical Unloaded Antenna Radiating at One of Its Harmonics", by Levin and Young, pp. 675-688.

[fol. 21] Proceedings I. R. E., Vol. 15, May, 1927—Discussion re above, pp. 439-443.

Proceedings I. R. E., Vol. 15, May, 1927—"High Angle Radiation of Short Electric Waves", by Uda, pp. 377,383.

(4) As to Lindenblad Patent No. 1,927,522—

United States Patents

No.	Inventor	Issue Date
741,622	Brown	Oct. 20, 1903
749,131	DeForest	Jan. 5, 1904
794,334	Artom	July 11, 1905
795,762	Garcia	July 25, 1905
808,594	Artom	Dec. 26, 1905
918,255	Athearn	Apr. 13, 1909
992,791	McElroy	May 23, 1911
1,020,032	Fessenden	Mar. 12, 1912
1,116,588	Harrison	Nov. 10, 1914
1,147,010	Fessenden	July 20, 1915
1,353,735	Espenschied	Sept. 21, 1920
1,360,167	Alexanderson	Nov. 23, 1920
Re-15,040	Franklin	Feb. 15, 1921
Re-15,041	Franklin	Feb. 15, 1921
1,370,735	Franklin	Mar. 8, 1921
1,562,961	Heising	Nov. 24, 1925
1,643,323	Stone	Sept. 27, 1927
1,658,740	Rice	Feb. 7, 1928
1,683,739	Stone	Sept. 11, 1928

British Patents

11,427/1903
223,742/1924
233,346/1926
251,638/1927

French Patents

593,570, Published Aug. 26, 1925;
Add. 30,798, Published Aug. 23, 1926.

Publications

[fol. 22] Maxwell's Theory and Wireless Telegraphy, by Poincaré—Vreeland, published 1904, McGraw Pub. Co., p. 94.

The Electrician, December 18, 1914—"The Possibility of Sharp Direction Wireless Telegraphy", by Bellini, pp. 352-354.

Proceedings of Physical Society of London, Vol. 29, 1917, "Radiation from Antennae", Van der Pol, pp. 269-289.

The Wireless Age, September, 1921, pp. 36-37—"Better Antennas", by D. W. Richardson.

Proceedings I. R. E., Vol. 12, October, 1924—"On the Optimum Transmitting Wave Length for a Vertical Antenna at Wavelengths Below the Fundamental", by Stuart Ballantine, pp. 823-832.

Proceedings I. R. E., Vol. 13, April, 1925—Discussion re above, pp. 251-255.

Q. S. T., August, 1926—"Straightening Out the Antenna", by Melton, pp. 30-32.

Proceedings I. R. E., Vol. 14, October, 1926—"Field Distribution and Radiation Resistance of a Straight Vertical Unloaded Antenna Radiating at One of Its Harmonics", by Levin and Young, pp. 675-688.

Proceedings I. R. E., Vol. 15, May, 1927—Discussion re above, pp. 439-443.

[fol. 23] Proceedings I. R. E., Vol. 15, May, 1927—"High Angle Radiation of Short Electric Waves", by Uda, pp. 377-383.

(b) Because said patents, and each thereof, disclose no patentable invention over and in view of the state of the

art at and prior to the time application for patent on each of said patents was filed and as illustrated by the instances thereof referred to in paragraph (a) hereof.

(c) Because the invention claimed in the original of each of said patents is substantially different from any indicated, suggested, or described in the original application therefor.

(d) Because the patentee of each of said patents surreptitiously or unjustly obtained the patent for that which was in fact the invention of another who was using reasonable diligence in adapting and perfecting the same. Instances thereof are as follows:

(1) As to Carter Patent No. 1,623,996—

United States Patents

No.	Inventor	Issue Date
1,475,997	Hoyt	Dec. 4, 1923
1,487,308	Beverage	Mar. 18, 1924
1,495,221	Clark	May 27, 1924
1,537,101	Whiting	May 12, 1925
1,562,961	Heising	Nov. 24, 1925
1,602,085	Rice-Kellogg	Oct. 5, 1926
1,602,086	Rice-Kellogg	Oct. 5, 1926
1,676,240	Affel	July 10, 1928
1,690,233	Kupfmuller	Nov. 6, 1928

[fol. 24] (2) As to Carter Patent No. 1,909,610—

United States Patents

No.	Inventor	Issue Date
1,778,395	Lindenblad	Oct. 14, 1930
1,868,795	Hansell	July 26, 1932
1,874,966	Green	Aug. 30, 1932
1,893,136	Franklin-Green	Jan. 3, 1933
1,898,180	Hansell	Feb. 21, 1933
1,901,025	Franklin	Mar. 14, 1933

(3) As to Lindenblad Patent No. 1,884,006—

United States Patents

No.	Inventor	Issue Date
1,683,739	Stone	Sept. 11, 1928
1,708,515	Meissner	Apr. 9, 1929
1,740,370	Rice	Dec. 17, 1929
1,740,371	Rice	Dec. 17, 1929
1,759,000	Chapman	May 20, 1930
1,775,801	Alexanderson	Sept. 16, 1930
1,788,022	Heising	Jan. 6, 1931
1,790,646	Alexanderson	Feb. 3, 1931
1,821,402	Peterson	Sept. 1, 1931
1,821,936	Franklin	Sept. 8, 1931

(4) As to Lindenblad Patent No. 1,927,522—

United States Patents

No.	Inventor	Issue Date
1,708,515	Meissner	Apr. 9, 1929
1,740,370	Rice	Dec. 17, 1929
1,740,371	Rice	Dec. 17, 1929
1,759,000	Chapman	May 20, 1930
1,775,801	Alexanderson	Sept. 16, 1930
1,788,022	Heising	Jan. 6, 1931
1,790,646	Alexanderson	Feb. 3, 1931
1,821,402	Peterson	Sept. 1, 1931
1,821,936	Franklin	Sept. 8, 1931
1,738,459	Stanley	Dec. 3, 1929

[fol. 25] (e) Because for the purpose of deceiving the public the description and specification filed in the Patent Office in each of the said cases was made to cover less than the whole truth relevant to the invention, or was made to cover more than was necessary to produce the desired effect.

(f) Because the description of the invention in the specification of each of said patents is not in such full, clear, concise, and exact terms as to enable any person skilled in the art or science to which it pertains or with which it is most nearly connected to make, construct, compound, and use the same.

(g) Because the invention of each of said patents was known to others and/or in public use and/or on sale before the alleged invention by each of the said patentees, or more than two years prior to the filing of application for Letters Patent therefor.

7. Further answering the bill of complaint defendant asserts that plaintiff comes to this Court of equity with unclean hands and is barred by principles of equity and by estoppel from equitable relief.

8. Further answering the bill of complaint defendant asserts that plaintiff is debarred from the relief prayed for, or to any equitable relief, by reason of its laches in asserting its claims as against this defendant with respect to said Letters Patent, and each thereof.

[fol. 26] Wherefore defendant denies that plaintiff is entitled to the relief prayed for, or to any relief, and there-

fore prays to be hence dismissed with its costs in this cause sustained, and for such other and further relief as to the Court may seem just.

Mackay Radio & Telegraph Company, Inc., by Samuel E. Darby, Jr., Its Attorney. Darby & Darby, Attorneys for Defendant, #405 Lexington Avenue, New York City, N. Y. Hugh M. Morris, Samuel E. Darby, Jr., of Counsel.

Dated, New York, N. Y., May 15, 1934.

[fol. 27] In United States District Court, Eastern District of New York

[Title omitted]

Motion for Leave to File Supplemental Bill

Now comes Radio Corporation of America, the plaintiff in the above entitled cause, by Sheffield & Betts, its solicitors, and moves this Court for an order granting leave to plaintiff to file herein the annexed supplemental bill of complaint and for such other and further relief as may seem to the Court to be just and proper.

Dated, New York, October 4, 1934.

Sheffield & Betts, Solicitors for Plaintiff. Abel E. Blackmar, Jr., of Counsel.

[fol. 28] In United States District Court, Eastern District of New York

[Title omitted]

Order Allowing Supplemental Bill

Upon the pleadings and proceedings heretofore had herein and upon the annexed motion of plaintiff for an order granting plaintiff leave to file the annexed supplemental bill of complaint, the defendant not opposing said motion, it is hereby

Ordered that the said motion of plaintiff be and the same hereby is granted and that leave be and hereby is granted

to plaintiff to file herein the annexed supplemental bill of complaint.

Dated Oct. 5, 1934.

Mortimer W. Byers, U. S. D. J.

Defendant not opposing plaintiff's motion hereinabove referred to, entry of the foregoing order without further notice is hereby consented to.

Darby & Darby, Solicitors for Defendant.

[fol. 29] In United States District Court

[Title omitted]

Supplemental Bill of Complaint

To the Honorable the Judges of the United States District Court for the Eastern District of New York:

The plaintiff, by this, its supplemental bill of complaint, alleges as follows:

1. That on or about April 21, 1934, plaintiff filed its original bill of complaint for the infringement by defendant of United States Letters Patent Nos. 1,623,996, 1,884,006, 1,927,522, and 1,909,610; that on or about May 15, 1934, defendant duly appeared herein and filed its answer to said original bill; and that other proceedings have duly been had herein.

2. That defendant has a regular and established place of business in the County of Suffolk, State of New York, in the Eastern District of New York, and has committed, is now committing, and threatens to continue to commit acts of infringement of United States Letters Patent No. 1,974,387 hereinafter mentioned, within said Eastern District of New York.

[fol. 30] 3. Upon information and belief, that Philip S. Carter, being the first, true, original, and sole inventor or discoverer of certain new and useful improvements in an "Antenna", not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, or

more than two years prior to his application for Letters Patent in the United States, hereinafter mentioned, and not in public use or on sale in this country for more than two years prior to the date of his said application, and not abandoned, and not patented or caused to be patented by him or his legal representatives or assigns in any country foreign to the United States on any application filed more than twelve months prior to his said application, and being then the owner of the entire right, title and interest in and to said invention or discovery and improvements, did, on or about June 5, 1930, by an instrument in writing, duly executed and delivered on or about said day, and recorded in the United States Patent Office June 11, 1930, duly sell and assign to the plaintiff, Radio Corporation of America, its successors and assigns, the said improvements, and the hereinafter mentioned application for Letters Patent of the United States therefor and all Letters Patent which might be granted therefor, and authorized and requested the Commissioner of Patents to issue such Letters Patent to the plaintiff as the assignee of the entire interest.

4. That on or about June 11, 1930, an application in writing for the grant of Letters Patent upon said invention or [fol. 31] discovery and improvements was duly made and filed with the Commissioner of Patents of the United States on behalf of said Philip S. Carter.

5. That Letters Patent numbered 1,974,387 were, on September 18, 1934, duly issued upon the aforesaid application, all the provisions and requirements of the statutes of the United States in such cases made and provided having been duly complied with, said patent being issued to the plaintiff, Radio Corporation of America, its successors and assigns, whereby there was granted to it and then for the term of seventeen years from the date thereof, the exclusive right to make, use and vend the invention or discovery and improvements set forth, described and claimed therein, throughout the United States and the Territories thereof.

6. That the plaintiff has been ever since the grant of said Letters Patent No. 1,974,387, and now is, the sole and exclusive owner thereof and of all claims for profits and damages for past infringement thereof.

7. That the plaintiff asks that the aforesaid assignment and Letters Patent No. 1,974,387 be deemed and taken as

a part of this bill of complaint, and asks leave to refer to the originals of the same or duly authenticated copies thereof, now in its possession and ready in Court to be produced.

8. That the plaintiff and one or more of its licensees have [fol. 32] expended large sums of money in making the inventions, discoveries and improvements of said Letters Patent No. 1,974,387 useful to the public and themselves; that the same have been practiced, and are now being practiced, by one or more of the licensees of the plaintiff; that the same have been and are of great value, importance, benefit and advantage to the plaintiff and its licensees and to the public; and that the invention, discovery, and improvements of said Letters Patent are capable of conjoint use with those of the said Letters Patent Nos. 1,623,996, 1,884,006, 1,927,-522, and 1,909,610, referred to in said original bill of complaint, in one and the same structure and system, and have been and are being so used by the defendant.

9. That prior to the execution of this supplemental bill of complaint, the defendant was duly notified of its infringement of said Letters Patent No. 1,974,387 and, as plaintiff is informed and believes, the defendant continued, after such notice, to use the invention of said Letters Patent.

10. Upon information and belief, that since the date of issuance of said Letters Patent No. 1,974,387 and without right, license or consent of the plaintiff, and within the Eastern District of New York and elsewhere within the United States, the defendant, Mackay Radio & Telegraph Company, Inc., has used and caused to be used devices, apparatus, structures, and systems embodying and employing the invention, discovery, and improvements of said Letters Patent and in infringement thereof, and also material and substantial parts of the invention, discovery and improvements of said Letters Patent, and now is continu-[fol. 33] ing and threatening to continue to commit said acts of infringement; and that some or all of the devices, apparatus, structures, and systems so complained of in this supplemental bill of complaint are also complained of in said original bill of complaint.

11. Upon information and belief, that the defendant has derived and received and will derive and receive from the

aforesaid infringement gains, profits, and advantages, but to what amount the plaintiff is not informed and cannot set forth; that the plaintiff and its licensees, by reason of the said infringement by the defendant, have been and will be deprived of and prevented from receiving, if such infringement is not restrained by this Court, gains, profits and advantages to which the plaintiff and its licensees are lawfully entitled and which they would have derived and received and would now be deriving and receiving but for the aforementioned infringement; that by reason of the aforesaid infringement the plaintiff and its licensees have been irreparably injured and have sustained losses and damages thereby; that the said infringement by the defendant has had and will have the effect of encouraging and inducing others to venture to infringe upon said Letters Patent No. 1,974,387; and that, unless the said infringement by the defendant is enjoined by this Court, further irreparable injury, loss and damage will be caused to the plaintiff and its licensees.

The plaintiff therefore prays:

I. That the defendant, Mackay Radio & Telegraph Company, Inc., and its directors, officers, associates, attorneys, [fol. 34] clerks, servants, agents, workmen and employees, be perpetually enjoined and restrained by a decree of this Court from directly or indirectly making or causing to be made, using or causing to be used, leasing or causing to be leased, selling or causing to be sold, advertising or offering for sale, use and lease, or causing to be advertised or offered for sale, use and lease, agreeing or contracting to sell and lease, causing to be agreed or contracted for sale and lease, supplying or causing to be supplied, installing or causing to be installed, threatening to offer or contract for sale, lease, and supply, or disposing of in any manner, devices, instruments, appliances, apparatus, structures, or systems embodying or employing the invention or discovery or improvements of said Letters Patent No. 1,974,387 or any substantial, material, or vital part or parts of said Letters Patent, and from infringing upon or contributing to the infringement of, or encouraging, inducing or aiding the infringement of said Letters Patent in any way whatsoever.

II. That a preliminary injunction issue against said defendant to the same tenor and effect as hereinbefore prayed for in respect to said perpetual injunction.

III. That said defendant be decreed to account to the plaintiff for all such gains, profits and advantages as have accrued to or have been earned or received by said defendant and also for all damages the plaintiff has sustained by said infringement, and that the Court assess the same, or [fol. 35] cause them to be assessed under its direction and increase the same as provided by law.

IV. That the said defendant be decreed to pay the costs, charges, and disbursements of this suit.

V. That the parties hereto shall be allowed full benefit of all the pleadings and proceedings had herein.

VI. That the plaintiff have such other and further relief as the premises and the equity of the case may require and to the Court may seem just.

Radio Corporation of America, by Otto S. Schairer, Its Vice-President. Sheffield & Betts, Solicitors for Plaintiff. Abel E. Blackmar, Jr., Of Counsel for Plaintiff.

[fol. 36] *Duly sworn to by Otto S. Schairer. Jurat omitted in printing.*

[fol. 37] In United States District Court, Eastern District of New York

[Title omitted]

Answer to Supplemental Bill of Complaint

The defendant, for answer to the supplemental bill of complaint herein, or to as much thereof as it is advised is necessary or material to be answered, on information and belief says:

1. Answering paragraph 2 of the supplemental bill of complaint, defendant denies that it has committed or threatens to commit acts of infringement of Letters Patent No.

1,974,387, either in the Eastern District of New York or elsewhere.

2. Defendant denies each and every allegation contained in paragraphs 3, 4 and 5 of the supplemental bill of complaint, except that it admits having seen what purported to be a printed, uncertified copy of Patent No. 1,974,387 issued to plaintiff, Radio Corporation of America, its successors and assigns.

3. Defendant is uninformed, save by the supplemental bill of complaint, as to the matters alleged in paragraph [fol. 38] 6 thereof, and therefore leaves plaintiff to its proofs.

4. Defendant denies each and every allegation contained in paragraphs 8, 9, 10 and 11 of the supplemental bill of complaint.

5. Further answering the supplemental bill of complaint, defendant affirmatively asserts that it does not infringe said Letters Patent.

6. Further answering the supplemental bill of complaint, defendant asserts that said Letters Patent is wholly void and invalid at law for each of the following reasons, to wit:

(a) Because the alleged invention of said Letters Patent was shown and/or described in printed publications of the United States and countries foreign to the United States before the alleged invention of the said patentee, and/or more than two years prior to the filing of the application for patent on which the said patent issued as follows:

United States Patents

No.	Inventor	Issue Date
663,400	Wilson and Evans	Dec. 4, 1900
741,622	Brown	Oct. 20, 1903
749,131	DeForest	Jan. 5, 1904
760,463	Marconi	May 24, 1904
794,334	Artom	July 11, 1905
795,762	Garcia	July 25, 1905
808,594	Artom	Dec. 26, 1905
924,560	Marconi	June 8, 1909
992,791	McElroy	May 23, 1911
1,020,032	Fessenden	Mar. 12, 1912
1,101,914	Fessenden	June 30, 1914
1,116,588	Harrison	Nov. 10, 1914
1,147,010	Fessenden	July 20, 1915

[fol. 39]

No.	Inventor	Issue Date
1,360,167	Alexanderson	Nov. 23, 1920
1,370,735	Franklin	Mar. 8, 1921
1,491,372	Alexanderson	Apr. 22, 1924
1,562,961	Heising	Nov. 24, 1925
1,643,323	Stone	Sept. 27, 1927
1,658,740	Rice	Feb. 7, 1928
1,683,739	Stone	Sept. 11, 1928
1,708,515	Meissner	Apr. 9, 1929
1,740,370	Rice	Dec. 17, 1929
1,775,801	Alexanderson	Sept. 16, 1930
1,788,022	Heising	Jan. 6, 1931
1,790,646	Alexanderson	Feb. 3, 1931
1,821,936	Franklin	Sept. 8, 1931
1,827,054	Von Arco	Oct. 13, 1931

Foreign Patents

British

11,427/1903
233,346/1926
251,638/1927
295,693/Jan. 31, 1929
299,447/Feb. 28, 1929

French

593,570 Published Aug. 26, 1925
Add. 30,798 Published Aug. 23, 1926

Publications

Widemann's Annalen der Physik, 1898, pp. 435-472—Abraham.

Physikalische Zeitschrift, March 2, 1901, pp. 329-334—Abraham.

Maxwell's Theory and Wireless Telegraphy, by Poincaré—Vreeland, published 1904, McGraw Pub. Co., p. 94.

[fol. 40] The Electrician, March 8, 1912, pp. 868-870.

The Electrician, December 18, 1914, pp. 352-354.

Proceedings Physical Society of London, Vol. 29, 1917, pp. 269-289—Van der Pol.

Proceedings I. R. E., Vol. 12, October, 1924, pp. 833-839—Ballantine.

Proceedings I. R. E., Vol. 12, October, 1924, pp. 823-832—Ballantine.

Proceedings I. R. E., Vol. 13, April, 1925, pp. 251-255.

Q. S. T., August, 1926, pp. 30-32—"Straightening Out the Antenna."

Proceedings I. R. E., Vol. 14, October, 1926, pp. 675-688—Levin-Young.

Proceedings I. R. E., Vol. 15, May, 1927, pp. 439-443—Levin-Young.

Proceedings I. R. E., May, 1927, pp. 377-385—Uda.

(b) Because said patent discloses no patentable invention over and in view of the state of the art at and prior to the time the application for said patent was filed and as illustrated by the instances thereof referred to in paragraph (a) hereof.

(c) Because the invention claimed in said patent is substantially different from any indicated, suggested or described in the original application therefor.

(d) Because the patentee surreptitiously or unjustly obtained the patent for that which was in fact the invention of [fol. 41] another who was using reasonable diligence in adapting and perfecting the same. Instances thereof are as follows:

Lindenblad Patent No. 1,884,006, granted Oct. 25, 1932, on an application filed Sept. 7, 1928.

Bruce Patent No. 1,899,410, granted Feb. 28, 1933, on an application filed Oct. 11, 1929.

Lindenblad Patent No. 1,927,522, granted Sept. 19, 1933, on an application filed Dec. 24, 1928.

(e) Because for the purpose of deceiving the public the description and specification filed in the Patent Office as part of the application for said patent was made to cover less than the whole truth relevant to the invention, or more than was necessary to produce the desired effect.

(f) Because the description of the invention in the specification of said patent is not in such full, clear, concise and exact terms as to enable any person skilled in the art or science to which it pertains or with which it is most nearly connected to make, construct, compound and use the same.

(g) Because the invention of said patent was known to others and/or in public use and/or on sale before the al-

leged invention by the said patentee, or more than two years prior to the filing of application for Letters Patent therefor.

7. Further answering the supplemental bill of complaint, defendant asserts that plaintiff comes to this Court of [fol. 42] Equity with unclean hands and is barred by principles of equity and by estoppel from equitable relief.

Wherefore, defendant denies that plaintiff is entitled to the relief prayed for, or to any relief, and therefore prays to be hence dismissed with its costs in this cause sustained, and for such other and further relief as to the Court may seem just.

Mackay Radio and Telegraph Company, Inc., by Samuel E. Darby, Jr., Its Attorney. Darby & Darby, Attorneys for Defendant, #405 Lexington Avenue, New York City, N. Y. Hugh M. Morris, Samuel E. Darby, Jr., Of Counsel.

Dated, New York, N. Y., November 23, 1934.

[fol. 43] In United States District Court, Eastern District of New York

E 7234

Radio Corporation of America, Plaintiff,

vs.

Mackay Radio & Telegraph Co., Inc., Defendant

Before Hon. Marcus B. Campbell, U. S. D. J.

Statement of Evidence

Brooklyn, N. Y., January 2, 1935.

Appearances

Sheffield & Betts, Esqs., Solicitors for Plaintiff; Jo. Baily Brown, Esq., Abel E. Blackmar, Jr., Esq., and Harry Tunick, Esq., of Counsel.

Darby & Darby, Esqs., Solicitors for Defendant; Hon. Hugh M. Morris, Samuel E. Darby, Jr., Esq., and Paul Kolisch, Esq., of Counsel.

Mr. Blackmar: If your Honor please, I offer in evidence a copy of each of the five patents in suit, suggesting that they be marked in this order: First Carter patent No. 1,623,996.

(Marked Plaintiff's Exhibit 1 in evidence.)

[fol. 44] Mr. Blackmar: The second Carter patent No. 1,909,610.

(Marked Plaintiff's Exhibit 2 in evidence.)

Mr. Blackmar: Then the first Lindenblad patent No. 1,884,006.

(Marked Plaintiff's Exhibit 3 in evidence.)

Mr. Blackmar: Then the second Lindenblad patent No. 1,927,522.

(Marked Plaintiff's Exhibit 4 in evidence.)

Mr. Blackmar: Then the third Carter patent, 1,974,387.

(Marked Plaintiff's Exhibit 5 in evidence.)

Mr. Blackmar: I have a stipulation covering certain formal matters. The stipulation also covers notice, and may I ask Mr. Darby whether he will concede that these V type antennas were used by the defendant between the date of notice and the commencement of the suit?

Mr. Darby: Oh, surely.

Mr. Blackmar: And also as to the third Carter patent, between the date of that notice and the filing of the supplemental bill?

Mr. Darby: We will concede that we used it since; that will be sufficient for your purposes.

Mr. Blackmar: And any question as to accounting, if any, may be left until that time on that basis.

Mr. Darby: All right.

(The stipulation referred to is marked Plaintiff's Exhibit 6 in evidence and is as follows:)

[fol. 45] PLAINTIFF'S EXHIBIT 6

STIPULATION

"It is Hereby Stipulated and Agreed, solely for the purposes of this suit, by and between the solicitors for the respective parties hereto, as follows:

"1. That certified copies of such United States Letters Patent as the parties may desire to introduce in evidence at the trial of this cause, need not be furnished, but that the usual printed copies supplied by the United States Patent Office shall be sufficient proof of the issue of such Letters Patent and of the contents thereof, provided, however, that correction may be made should error appear, and provided further that such printed copies shall not be used as evidence of the dates of filing or of the contents of the applications on which the Letters Patent were granted.

"2. That certified or exemplified copies of such foreign Letters Patent as the parties may desire to introduce in evidence at the trial of this cause, need not be furnished, provided printed copies thereof are available, but that photostatic copies of such Letters Patent, such as are obtainable from the United States Patent Office or The New York Public Library may be offered in evidence and shall be sufficient proof of the issue of such Letters Patent and of the contents thereof and of the dates stated thereon, provided, however, that correction may be made should error appear.

"3. That photostatic copies of publications may be offered in evidence by either party with the full force [fol. 46] and effect of the originals thereof, and that such copies shall be sufficient proof of the publication thereof at the dates appearing thereon, provided, however, that either party, upon reasonable notice thereof to the other party, may question either the fact or date of publication of any of said publications and require the other party to make proof thereof, and that correction may be made should error appear.

"4. That the defendant, Mackay Radio & Telegraph Company, Inc., commenced the construction of its first 'V-type' antennas early in June, 1932, and first placed them in commercial operation early in July, 1932.

"5. That plaintiff notified the defendant, on or about April 20, 1934, that it considered that defendant was infringing the Letters Patent here in suit Nos. 1,623,996, 1,884,006, 1,909,610 and 1,927,522; and that plaintiff notified the defendant, on or about September 24, 1934, that it considered that defendant was infringing Letters Patent No. 1,974,387, here in suit.

"6. That the paper submitted herewith and entitled 'Description of Sayville Antenna No. 8' (taken together with the diagram annexed thereto entitled 'Exhibit A, WMZ-20 Antenna System') is a true and correct statement of the facts therein set forth (subject to correction should error appear). And that, similarly, the papers submitted herewith and entitled 'Description of Sayville Antenna No. 10', 'Description of Sayville Antenna No. 1', 'Description of Sayville Antenna No. 2', 'Description of Sayville Antenna [fol. 47] No. 11', and 'Description of Sayville Antenna No. 7' (taken together with the diagrams annexed thereto and respectively entitled 'Exhibit B, WKT Antenna System', 'Exhibit C, WIU Antenna System', 'Exhibit D, WML Antenna System', 'Exhibit E, WKS Antenna System', and 'Exhibit F, WSE Antenna System') are true and correct statements of the facts therein set forth (subject to correction should error appear). And that the dimensions and other data set forth on the two sheets marked 'Exhibit G—Tabulation of Dimensional Data for V-Antennas at Sayville' are true and correct (subject to correction should error appear).

Dated, New York, N. Y., December 4, 1935.

"Sheffield & Betts, Solicitors for Plaintiff. "Darby & Darby, Solicitors for Defendant."

Mr. Blackmar: I now offer in evidence the agreed description of the Sayville Antenna No. 8, together with a diagram thereof, which has been marked Exhibit A.

(Marked Plaintiff's Exhibit 7 in evidence.)

Mr. Blackmar: I also offer in evidence description and diagram marked Exhibit B, with respect to the Sayville Antenna No. 10.

(Marked Plaintiff's Exhibit 8 in evidence.)

Mr. Blackmar: I also offer in evidence the description and diagram marked Exhibit C of the Sayville Antenna No. 1.

(Marked Plaintiff's Exhibit 9 in evidence.)

[fol. 48] Mr. Blackmar: I similarly offer in evidence the description and diagram marked Exhibit D of the Sayville Antenna No. 2.

(Marked Plaintiff's Exhibit 10 in evidence.)

Mr. Blackmar: I similarly offer in evidence the description and diagram marked Exhibit E of the Sayville Antenna No. 11.

(Marked Plaintiff's Exhibit 11 in evidence.)

Mr. Blackmar: I similarly offer in evidence the description and diagram marked Exhibit F of the Sayville Antenna No. 7.

(Marked Plaintiff's Exhibit 12 in evidence.)

Mr. Blackmar: I also offer two sheets annexed to the stipulation, marked Exhibit G, constituting a tabulation of dimensional data.

(Marked Plaintiff's Exhibit 13 in evidence.)

Clarence W. Hansell, called as a witness on behalf of the plaintiff, having been duly sworn, testified as follows:

Direct examination.

By Mr. Brown:

The Witness: I reside at Port Jefferson, New York, am a radio engineer, and am a graduate engineer also.

I have charge of the transmitter research and development laboratory of RCA Communications, Inc., at Rocky Point, Long Island. My understanding is that that com- [fol. 49] pany is a wholly-owned subsidiary of RCA, by which I mean the Radio Corporation of America; it is the Communications subsidiary of the parent company.

My first experience in radio communication was obtained in 1918 from a short course in the Student Training Corps of the United States Army at Purdue University. Then I graduated from Purdue University in June of 1919 and I was employed after that by the General Electric Company at Schenectady, New York.

In 1920, while I was working for the General Electric Company, I was put in charge of tests on the Alexanderson high frequency alternators which were being manufactured by the General Electric Company for installation in transoceanic stations of the Radio Corporation of America. By Alexanderson high frequency alternators, I mean the ma-

chines that generate the currents used for transmitting signals.

I was transferred to the Radio Corporation of America in September of 1920. I then became one of several assistants to Mr. E. F. W. Alexanderson, who was then chief engineer of the Radio Corporation of America, and under Mr. Alexanderson I worked on quite a large variety of research, development, and design problems connected with trans-oceanic and marine transmitting stations.

I assisted in the design of the station at Rocky Point. I am familiar, in a general way, in most respects, with the work of the Radio Corporation of America in the development of directive antennas for long distance short wave communications. According to my recollection, the Radio [fol. 50] Corporation of America first worked on directive antennas for short wave, long distance communication in 1923.

The first work done by the Radio Corporation of America, so far as I can recollect and am aware of it, was done at Belfast, Maine, and I was one of those engaged in the tests which were made there. In the very first directive antenna experiment, Mr. H. H. Beverage, Mr. S. W. Dean, who was at that time my assistant, and myself, transmitted from Belfast, Maine, to Riverhead, Long Island, where Mr. H. O. Peterson made observations of the received signals and following that, throughout the early part of 1924, I spent all my spare time in doing directive antenna experiments at Belfast, Maine.

That Belfast station was established primarily for the purpose of receiving long wave trans-oceanic signals from Europe and relaying them on down to Riverhead, Long Island, and from there into New York City; that was commercial communications.

We were using, for receiving those signals from Europe, what was known as the Beverage wave antenna, which consisted of the equivalent of a pair of wires about ten miles or one wave length long, and these wires gave an antenna with a considerable amount of directivity for reception of long wave signals. These wires were directed in the direction of the signal to be received. They were just two wires side by side on telegraph poles; the antenna looked very much like an ordinary telegraph line.

As to what we did there in 1923 and 1924 in the way of trying to send, or sending, short wave radio signals from [fol. 51] the antennas which we had there, our first experiment, that I mentioned before, was done by taking a section of that long wave receiving antenna and using it for transmission. Its direction happened to be pointing very close to Riverhead, a direction opposite to Europe. So one Sunday we applied energy to the end of that antenna from our transmitter and had Peterson at Riverhead observe the received signal as compared with the signal from our normal relay antenna. For the purpose of that test the line of the wave antenna was cut off at about 4600 meters, as I recollect, and there we placed a resistance between the antenna and ground, with the object of making radiation unidirectional, if we could. That is, we cut into this long antenna to get the length we wanted, and then we used that section. We thought that if we made the length too great for the wave length which we used for transmission, the directional effect probably would not be so good as if we used a moderate length, so we cut it off at a little less than three wave lengths. The wave length that we used for relaying to Riverhead was 1620 meters.

We used other antennas and other wave lengths in our experiments there. A week after this first experiment, we set up a very small model of wave antenna on the station grounds, it was about one meter high and ten meters long, and we used a wave length of twelve meters. The energy was applied to one end of the antenna and we carried a receiver around the antenna to try and find the directional characteristics and apparently there was an appreciable amount of directional effect in line with the antenna in the [fol. 52] direction away from the end at which the energy was applied. We tried out three different types of antennas there, altogether. We built another one, later on, whose length varied according to the experiments being made. I think the greatest length that I used was 1400 meters. I made many changes in that antenna in an attempt to find a means of producing a good short wave directional antenna. None of the antennas that we worked with there for transmitting short waves went into commercial use at that time as a result of these experiments. We did not develop any antenna at that time that was sufficiently promising to

continue with, as a line of development; none of them seemed good enough at that time.

In the latter part of 1924, RCA began to use short waves commercially.

In the latter part of the year, probably about September, a transmitter was installed at the Tuckerton, New Jersey, station, which operated on wave lengths in the neighborhood of 100 meters. I haven't the exact date of that.

They were using short waves for sending to California, Buenos Aires, and other places, in 1924. This first transmitter was installed primarily for operation to Europe and Buenos Aires, Argentine, and it was followed in the same year by two other transmitters at New Brunswick, New Jersey, and two at Rocky Point, Long Island, and one at Bolinas, California. The transmitter in California was for transmission to Hawaii and the Orient. These were all commercial circuits. No directional antenna was used in these transmitters at the transmitter end.

In the latter part of 1924 daylight signals were received for the first time from England. Short waves were used. [fol. 53] This reception was carried on at Riverhead, where our commercial receiving station was located, at Cape Cod, where we had a marine station, and I think at one other point, perhaps Tuckerton.

After our work at Belfast, RCA did not immediately continue experimental work on directive antennas, as far as I know. They discontinued it because in 1924 the General Electric Company took over the program of directive antenna development, and we were not permitted to duplicate their effort because of the expense, so we withdrew for the time being. At that time, the Westinghouse Company and General Electric Company were the engineering concerns in the development of this work, and RCA was a communication company only.

As to my familiarity with the work that was done by the General Electric Company in its development of short wave directive antenna, I had the job of attempting to keep familiar with the work carried on by General Electric and Westinghouse Companies for the benefit of RCA, and I made a number of trips to Schenectady and to East Pittsburgh, and on at least one occasion wrote a report on the status of their research and development along those lines. As to those in charge of this development for the General Elec-

tric Company, one group was headed by Mr. E. F. W Alexanderson, the man I mentioned before, and his assistant was Mr. S. P. Nixdorf. Another group working independently, but not very far away, was headed by Chester Rice and E. W. Kellogg. A little bit later a third group engaged in directive antenna development, and this group was headed by W. R. G. Baker; under him two engineers, Levin [fol. 54] and Young, I particularly remember as being very active. As one familiar with this radio art, I think Mr. Alexanderson ought to be classed as almost a famous radio engineer, at any rate, he was a leading man in this country in radio communication development at that time, and Rice and Kellogg were also very well known at that time and very highly regarded, and Mr. Baker was the head of the radio department of the General Electric Company, so I think he was very well qualified too.

These General Electric engineers continued on development of short wave directive antennas for a number of years, from about 1924 until 1926, intensively, and to some extent they continued with their work afterward, but so far as I know, substantially no commercial use has ever been made of the antennas which they developed or attempted to develop. They did develop some directive short wave transmission antennas, and they have been used for various experimental purposes, and perhaps for some broadcasting work.

Mr. Alexanderson and Mr. Nixdorf spent a large proportion of their time on development of large loop antennas and a little bit later they worked with arrays of di-pole antennas, hung up from steel towers. Rice and Kellogg worked on a form of multiple tuned antenna, and it was somewhat similar to the antenna which had been developed by Alexanderson, and later, engineers under Baker did some work on similar types of antennas and also some smaller types, such as vertical wires.

The General Electric Company's very active program terminated in 1926. As to why they discontinued this work [fol. 55] in 1926, my understanding is at that time the engineers were also interested in other developments, and in that same year the Marconi Company developed or demonstrated the beam system between England and Canada, which was so successful that it looked as if that type of antenna would be adopted as standard, and General Elec-

tric's efforts slacked off. That is what is commonly referred to as the British beam antenna.

As to what the RCA did in the way of adopting or using this British beam antenna in 1927, one of these antennas was erected at Rocky Point for transmission to England and a similar antenna was erected at Riverhead, for reception.

Q. 52. Mr. Hansell, now will you please tell us in a general way what that British beam unit was, and in this connection I hand you, so that you may use them if you see fit in your answer a blue print which is marked Marconi's Wireless Telegraph Co., Ltd., London, No. 32251/1 entitled "Schematic Diagram of Feeder Circuit & Aerial, Beam Stations" and also a blue print marked Marconi's Wireless Telegraph Co., Ltd., London, No. 35567, entitled "General Arrangement of Aerial & Reflector System Beam Transmitter, Rocky Point, New York." You may state what those prints are, if you know, and then briefly describe the antenna structures as shown by those prints.

A. Drawing No. 32251/1 is a schematic diagram to illustrate the Marconi beam antenna. This was furnished to RCA in 1926 at the time we were negotiating with the Marconi Company for the erection of one of these beam antennas. This drawing has been kept in the files of our head office at 66 Broad Street.

It shows in a general way the type of radiators used [fol. 56] and the feeder system for energizing those radiators.

Drawing No. 35567 is a construction drawing showing in outline the Marconi beam antenna which was erected at Rocky Point in 1927. This drawing has been kept in the Rocky Point station files for use in connection with maintenance of the antenna since it was erected.

Mr. Brown: I will offer in evidence as Plaintiff's Exhibit No. 14 the Marconi Wireless Telegraph drawing No. 32251/1 referred to by the witness.

(Marked Plaintiff's Exhibit 14 in evidence.)

Mr. Brown: And as Plaintiff's Exhibit No. 15 Marconi Wireless Telegraph Company drawing No. 35567 just referred to by the witness.

(Marked Plaintiff's Exhibit 15 in evidence.)

Q. 53. Will you please tell us in a general way what the structure of that antenna is and how it functions?

A. This drawing No. 35567 of the Marconi Company shows first of all three steel towers for supporting the antenna system. Those towers are each 300 feet high and have 75-foot cross arms at the top. Between the cross arms can be seen a system of cables. There are four cables in all for holding up two curtains or arrays of radiators. On one side of the center line of the row of towers are 32 radiator wires, each one of which is made up in a considerable number of sections, one above the other, and the sec- [fol. 57] tionalizing is indicated by means of what look from here like dots on the wire. Actually at those points there are very loosely wound coils, or a structure which serves the same purpose, for reversing the phase of currents in adjacent sections of each radiator. The result is that this whole system of radiators carries current which flows upward in all the radiators simultaneously or downward simultaneously. The coils that I refer to are shown on the other drawing that was mentioned a moment ago, that is, those criss-cross arrangements in the middle of the vertical line. Those in effect are the equivalents of extensions of the radiator wires, but, being folded up, they radiate very little, and consequently they gave the effect of a wire in which the radiations from alternate half wave sections are suppressed, and that results in the currents all flowing upward simultaneously in all the radiator wires and all parts of the radiator wires.

Behind the 32 radiator wires was placed a curtain of tuned reflector wires. Each of the reflector wires was made up of a series of half wave sections so adjusted as to be substantially tuned for the wave length being used on the antenna. The result was that waves leaving the 32 radiators left in both directions, forward at right angles to the line of towers and backwards at right angles to the line of towers, but the reflectors reversed the radiation in one direction and sent it back through the antenna and forward in such a phase that it added with the radiation in the forward direction so that in effect the radiation from both sides of that radiator system was made to go out in a single direction.

[fol. 58] It may be worth noticing the particular arrangement of the suspension cables between the tops of the towers.

It will be noticed that instead of running straight across, those cables are bent in a curved shape. When the first Marconi beam antennas were built, a single cable was used to support the antenna, and reflector, but serious trouble was encountered with that arrangement because of the wind bellying out the antenna in such a way that the radiations from the center portion would no longer add with the radiations from the end portion and the directivity was spoiled. So this double suspension system was resorted to, to reduce that swaying of the antenna in the wind.

Another important feature from the mechanical point of view is that each of these radiator wires forms a span against which the wind exerts a pressure at right angles. A relatively small amount of pressure at right angles to that span of wire can produce a relatively great tension at the point of support on the suspension cable.

That is a very well-known principle, that if a wire is stretched tight and a force applied at the center there is a resulting force at the ends very much greater than the force applied at the center. Similarly, this multiplied force applied to the suspension cable at these 32 points is applied to the suspension cable between the tops of the towers, and the actual force is very greatly multiplied for the same reason. The result is that the towers have to be made very heavy and very strong so that they will stand that great multiplication of force.

Those towers are marked 650 feet apart on the drawing, and that is my recollection,—650 feet between towers.

[fol. 59] That British beam antenna erected at Rocky Point is still in use. It has been in commercial use ever since it has been erected.

The receiving antenna at Riverhead is not still in use; its use has been discontinued for some time.

The experience of our company, in the matter of maintaining this British beam antenna in working condition, hasn't been any too good. Soon after the antenna was erected we began to have failures of these radiator wires due to breakages near their top suspensions. Those breakages became so frequent we had to replace the whole radiator system with heavier material; and we made that material as heavy as could be permitted without danger of pulling down the towers and supporting cables. But in spite of that the breakages still continue. Only yesterday I noticed five of these radiators were down on that antenna.

We have had a windstorm take out substantially all of these wires.

This is a photograph of the British beam antenna as erected at Rocky Point.

Mr. Brown: I will offer that in evidence as Plaintiff's Exhibit 16.

(Marked Plaintiff's Exhibit 16 in evidence.)

The Witness: I have at various times, in connection with our antenna development, tried to find out what the cost of that British beam transmitting antenna as it was erected at Rocky Point is, but the records were kept in such a way that I never was able to find out an exact figure. But we have found out the cost of various parts of the antenna [fol. 60] and estimated other parts for our own purposes, and the laboratory figure which we have used has been about $175,000. From the figures that we were able to find of the actual cost of that actual installation at Rocky Point, we were able to establish fairly definitely that the cost could not possibly have been less than $100,000.

The installation of this British beam antenna at Rocky Point did not end RCA's development and research on directive antennas for short waves. The result was that RCA again took up the development of directive antennas, and pushed it actively without waiting for results from the General Electric Company. RCA started its own efforts to develop a short wave directive antenna after 1924 at Rocky Point by means of the engineers in a group that was assigned to me; that is, under my charge. First Mr. Lindenblad was assigned to work under me on directive antennas, and shortly after that Mr. Carter and a number of others. Lindenblad had done a considerable amount of design work on long wave antennas; and Carter had taken part in the development of the Beverage wave antenna.

As a result of this development work at Rocky Point by these men, there have been four general types of directive short wave antennas developed and commercialized. We designated them as Models A, B, C, and D.

The Model A consisted of two horizontal feeder buses, across which were connected radiator wires and tuning coils. The dimensions of the radiator wires and tuning coils were so adjusted that the effective capacity of the feeder buses, considered as transmission lines, was tuned [fol. 61] out. That gave the feeder bus the equivalent of

almost infinite electrical velocity, and caused currents to flow in all the radiators in substantially the same phase. In making up the complete antenna a similar set of radiators with their feeder buses was erected parallel to the first and fed in 90-degree phase relation, with such a spacing as to get substantially unidirectional radiation. We began developing it in 1926 and the first full scale model was finished on April 3, 1927. The first commercial model, designed to handle commercial traffic was placed in service in September of 1927, and was operated on a wave length of 16.2 meters, for transmission from Rocky Point to Germany. This model A antenna was of the suspended or curtain type, somewhat like the English beam. It had a number of vertical wires with the feeder in the middle.

We described the Model A antenna fairly fully in a paper presented to the Institute of Radio Engineers by Messrs. Carter, Lindenblad, and myself. This paper was published in the October, 1931, Proceedings of the Institute of Radio Engineers. On page 1777 begins a section referring to the development of the Model A antenna. That continues to the end of page 1778. Some additional information is given on page 1784. On page 1790, in Fig. 10, is a photograph of one of the Rocky Point antennas, the Model A antennas, erected for commercial service from New York to San Francisco. On page 1777, Fig. 2, is an abbreviated schematic diagram of the type of arrangement used in the Model A. Equivalent circuits are shown again in Fig. 9, on page 1789, and a photograph of one of the antennas is shown [fol. 62] on page 1790. This photograph, marked 93900, which is on a larger scale, is a photograph of one of the commercially used type of Model A antennas; it is not the same one as shown in the paper, however, but is one that was erected at Rocky Point.

Mr. Brown: I offer that in evidence.

(Marked Plaintiff's Exhibit 17 in evidence.)

The Witness: The drawing marked Radio Corporation of America, Engineering Department, No. L-323, is an outline drawing of a model A antenna, or a portion of it at any rate, showing the dimensions in wave lengths. This drawing was made up in our laboratory and supplied to our design and drafting division in New York, so that they could make the designs of the commercial antennas, of which a large number were erected, based on this drawing.

Thirty-eight were erected altogether, referring to our records, in the United States, Philippines, Hawaii, China, Russia and Norway. So far as I know they are all still being used.

There were two means of making the tuning adjustment in this antenna. One was by means of coil adjustments,—the coils were installed between the feeder buses at a point of connection to the radiators,—and another method of adjustment was to vary the dimensions of the feeder bus. It was made in two parts and the spacing between could be varied. These coils do not show on the drawing before me; their position is only indicated by crosses. Drawing marked RCA V-622 shows the coils; in the center right-hand por- [fol. 63] tion of the drawing is shown the coil arrangement used for antennas where we never had sleet, where we did not have to worry about keeping sleet off the antenna, and in the upper left-hand part of the drawing is the arrangement of two coils, which we used when we had to make provision for sleet conditions.

The way that we adjusted these coils when this antenna was erected was to run a steel cable to the top of the poles at each end of a span and on that cable a man was pulled up in a boatswain's chair, and he had to be moved along this whole bus to make individual adjustments for each adjusting point in the antenna in order to tune it. These coils got out of adjustment once they had been adjusted. We had quite a lot of trouble with ice and snow bending them out of shape, and in some other cases, vibration due to wind would deform the coils and put the antenna out of tune.

Mr. Brown: I will offer in evidence as Plaintiff's Exhibit 18 a drawing L-323, that has been referred to by the witness.

(Marked Plaintiff's Exhibit 18 in evidence.)

Mr. Brown: And as Plaintiff's Exhibit 19, the RCA drawing V-622 as referred to by the witness.

(Marked Plaintiff's Exhibit 19 in evidence.)

The Witness: The first one of these Model A antennas went into service at Rocky Point in September, 1927.

[fol. 64] The Model B was the next commercial model of the antenna developed at Rocky Point, but we worked on another type before it was commercialized. We called that other type an expanding wire antenna, which consisted of

a two-wire transmission line, starting with the wires close together at one end, and the wires progressively increasing in spacing as we proceeded to the other end; there was no cross-connection. Right at that time no commercial model of that expanding wire antenna resulted, but it did lead to the development of an antenna which we called a Model B. We actually used that diverging wire antenna and in several instances the experimental antennas were used to handle commercial traffic for some time. This diverging wire antenna was not as directive as Model A; I do not believe that the models that we had were any of them as directive as Model A.

The next development of directive antennas by our group was when we call a Model B antenna, which was made up by means of long straight wires, arranged in such a way that their radiations would add in one desired direction and not add or more or less oppose in other directions. The fundamental radiating unit of that antenna consisted of two long wires which were excited in phase opposition, and so placed that their radiations would add in two general directions and cancel in two other general directions. Then a second pair of wires was set up to change that bi-directional antenna into a unidirectional antenna. Model B was described and illustrated in the paper for the Institute of Radio Engineers that we referred to previously. The de- [fol. 65] scription of the development begins at page 1779 and continues to about the middle of page 1781. At page 1806, Fig. 23, is a photograph of a two-bay Model B antenna, and Fig. 24 shows more in detail the feeder arrangement for one of these antennas. A schematic diagram is shown on page 1805, Fig. 22-A.

The first full-sized model B antenna for test was finished by our company on February 7, 1929, and the first commercial model for traffic was placed in operation on April 4, 1930. It operated on a wave length of 16.55 meters, and transmitted from Rocky Point to Madrid, Spain. Up to the present time, 25 of these model B antennas have been erected by RCA.

The model C was very similar to the model B except that the four wires forming the antenna were arranged in a horizontal instead of a vertical plane. Another difference which we made was to feed these radiator wires at their centers instead of at the ends, but so far as directivity and radiation characteristics are concerned, they were quite

similar. This model C antenna is described in our I.R.E. paper just referred to. It is shown schematically on page 1805, Fig. 22-B, and photographs are shown on page 1807. A complete antenna is shown in Fig. 25, and a portion of the antenna including the feeder arrangement in Fig. 26.

The first full-scale experimental model C antenna was finished by our company on April 10, 1929, and the first model for commercial service was placed in operation on July 7, 1930. It operated on a wave length of 28.22 meters, and transmitted from Rocky Point to Buenos Aires, Argen- [fol. 66] tine. We have built altogether six of these model C antennas.

The model D antenna which was developed at Rocky Point was an antenna which in some respects had a similarity to the expanding wire antenna, in that it used the long radiator wires set up at an angle to one another, and excited at their adjacent ends in phase opposition. The angle between the wires of one of these antennas was made such that the radiations from the two wires would add in one desired direction along the bisector of the angle, but would add much less favorably or even cancel in other directions.

As far as I know, practically all of the directive antennas we have built to date, including the models B and C, are still in use.

This Model D antenna, to which I have just referred, is also described in our I. R. E. article. The description of the development of that antenna begins about the middle of page 1781, and continues to the end of page 1783. On page 1819, Figs. 36 and 37 are schematic diagrams of the V type radiator used in setting up the model D antennas. On page 1820, Fig. 38 is a complete schematic diagram of a two deck model D antenna. Fig. 39 indicates that two of these might be used to obtain additional directivity and Fig. 40 is a modified arrangement when sleet melting is required. There are also quite a number of figures starting with Fig. 41 on page 1822, and continuing, which show the directive characteristics of V type antennas, having various lengths of radiators, and corresponding angles for the V's.

This paper to which I have referred was delivered orally before a meeting of the Institute of Radio Engineers on [fol. 67] June 6, 1931, at Chicago, and was published in the proceedings of that Institute in October of 1931. I personally delivered the paper in Chicago.

In my opinion, I would say that this I.R.E. paper describing the models B, C and D contains sufficient information as to structure, arrangement, and adjustments to enable a radio engineer to construct and operate the antennas there described.

Mr. Brown: I will offer in evidence as Plaintiff's Exhibit 20, the paper entitled "Development of Directive Transmitting Antennas by RCA Communications, Inc.", published in Vol. 19, No. 10 of the proceedings of the Institute of Radio Engineers, October, 1931.

(Marked Plaintiff's Exhibit 20 in evidence.)

The Witness: We set up the first full scale model D antenna for long distance tests in April, 1930, and made quite a long series of measurements with it, transmitting from Rocky Point to Marshall, California, and Koko Head, Hawaii, which are on substantially the same line. The first commercial model D antenna was placed in service at Bolinas, California, in November of 1930, call letters KWE, frequency, 15,430 kilocycles, that is approximately 20 meters wave length. There have been quite a large number of model D antennas erected, and including all the various modifications I have been able to locate in the last few weeks, there have been not less than forty of these erected [fol. 68] and operated by RCA and associated companies. There are a few which were more or less experimental ones which aren't in use, but I should say probably 35 to 38 of them are still in use.

My work as head of the RCA transmission laboratory at Rocky Point has made me familiar with the comparative costs of erection and maintenance of models A, B, C and D antennas, and of the British beam antenna. Naturally this is a portion of the development of any new type of antenna, to determine whether it would be economical to place it into use, and as a consequence of that, we spent quite a bit of time trying to determine relative costs. For our comparisons of the cost of erection of the models A, B, C and D antennas with each other and with the British beam antenna that was purchased by RCA Communications, we took a wave length of 20 meters as representative, since that is about the middle of the trans-oceanic band, which we use, and putting together all of the information we were able to collect at the time, we placed the cost of the Marconi beam

at $175,000, as I said before. To obtain the same power gain due to the directivity, in comparison with the half wave di-pole, the cost of the model A was $80,000, the model B $30,000, the model C $48,000—the model C, incidentally, is not recommended for that wave length—and the model D $5,000. These comparisons are based upon our estimate of these several antennas built at the same point and capable of delivering the same signal strength at a given point; they are based on the assumption of conditions similar to what we have at Rocky Point. At other locations, the cost of one type might be a little higher than another, or it is [fol. 69] possible that all of the costs might be higher or lower, depending on local conditions for obtaining material, and the character of the ground, and so forth.

As to the respective costs of maintenance in service of these several types of antennas, the Marconi beam has given us quite a large amount of trouble, and has required quite a large amount of maintenance. The model A was not quite so bad, but it also required considerable maintenance, but models B, C and D have required practically no maintenance at all.

As to how the models A, B, C and D and the British beam antenna compare in strength of signals delivered to a given point along the line of strongest directivity, that depends on the number of sections or bays of each antenna used; but assuming that one bay or section is to be used, then the comparative figures would be 10 for the model A, 16 for the model B, 17½ for the model C, 40 for the model D and 40 for the Marconi beam. I believe the figures are given in our I.R.E. paper for the A, B, C and D types, but not for the Marconi beam.

As to how the Marconi beam antenna and the model D compare with respect to the ability to deliver signal strength under similar conditions and similar distances, they are both capable of giving excellent directivity and a large amount of power gain, so that from the standpoint of directivity alone, there is not much choice between them. We can get the model D antenna to give us the same result we get from the British beam under similar conditions, and the cost of the model D is around $5,000 and the British beam between $100,000 and $175,000.

[fol. 70] RCA Communications has about 100, a little over 100, directive short wave antennas in service at the present time.

I spoke of a single bay of the model D antenna, as giving certain signal strength under certain conditions. I had in mind, as a single bay of the model D antenna, an antenna such as was shown in Fig. 38 on page 1820 of the I.R.E. paper. It consists of four model D type radiators, altogether, arranged as shown in the diagram.

If we left off, say, the two top V's of these single bays that I have talked about, I would estimate that the resultant change in effective signal strength under the conditions referred to, that is, the directivity, instead of being 40 per bay, might drop to 20 or 25 per bay. Then suppose we left off one of the two V's in a horizontal plane and used only a single V, that would give us a reduction in signal strength to one-half again or in the neighborhood of ten to twelve and a half.

RCA Communications has a number of single V antennas in service and has built others for temporary or experimental purposes.

We have measured the signal strength from the single V's and from the two single V's in the same horizontal plane.

I know in a general way what the English, French and German radio companies have used in the way of directive short wave antennas in those countries from, say, 1923 or 1924 up to 1930, particularly those companies associated with RCA in handling traffic. In 1924, I was asked to go to London with Mr. David Sarnoff, to attend a meeting where the development of short wave stations and equipment was to be discussed, and following the meeting I made [fol. 71] trips around England and to France and Germany to see what the engineers were doing on the development of directive antennas. Following that, I came back to the United States and made a report to my superior concerning it. In England, I found that they were working very intensively on the development of directive antennas and they, at that time, had worked out the general scheme and principles of the antenna which we now call the British beam, and they were at that time engaged in working out the detail mechanical features of it. The French, at Sainte Assize, under Mr. Chireix, were also very active in the development of directive antennas at that time, too, and had set up quite a large amount of experimental directive antenna installations at Sainte Assize station. The Germans

had not yet started development of directive antennas, but they were expecting to within a reasonably short time.

The only short wave directive antenna that I saw set up in full size for communication purposes in 1924, in any of these countries, was one which the Marconi Company had erected at Poldhu, in the southern tip of England, in Cornwall. This photograph is a general view of the arrangement of masts and the antenna system which I saw at Poldhu in 1924. The photograph has apparently been retouched considerably in order to make the wires and central parts of the system visible. I believe that a natural photograph would not show the antenna wires, but it does show the general arrangement which I saw there at that time. The antenna system consisted of a vertical radiator, a single vertical radiator wire, and around that had been [fol. 72] grouped a large number of reflector wires on a surface shaped according to a parabola. This antenna had been used by Marconi for experimental transmissions from England, in the general direction of Africa and in another instance towards the United States. To the best of my knowledge the Marconi parabolic antenna has never had any extensive commercial use for long distance communications; its ultimate or maximum obtainable directivity was too limited.

Mr. Brown: I will offer in evidence, if you please, the photograph referred to entitled "Poldhu Cornwall, 1923", as Plaintiff's Exhibit 21.

(Marked Plaintiff's Exhibit 21 in evidence.)

The Witness: The French developed an antenna having di-pole radiators formed by bent sections of wire up and down in sort of a grille work fashion, by means of which they obtained the equivalent of the currents flowing in phase throughout a curtain, just as was done in the Marconi beam. The mechanical features of the French antenna were double suspensions and heavy towers, and so on, substantially the same as the British.

I have seen the American Telephone & Telegraph Company short wave directive antenna at Lawrenceville, New Jersey. I saw it in 1929, probably in May, just before the station was opened for commercial service. Except for the details of the radiators, the radiators proper, the structure of the Telephone Company's directive antenna at

[fol. 76] Q. 142. Now, when you measure, you measure along a straight line, as I understand it, across the beam. How do you determine these particular points that are indicated in your graph?

A. We took our measurements in terms of relative power and made a correction for distance in accordance with the law that for the signal strength along the surface of the ground, the power falls off as the fourth power of the distance. We use this same law for correcting our own directive characteristics where we have to make such a correction.

Compared to our own practice, we used, for making these measurements, the same instrument that we had used at Rocky Point for making directive measurements of similar antennas.

Based on our measurements on similar antennas, the directive pattern from the single V type antennas, if they were properly adjusted, would not be very greatly different from that shown for WIU except that there would be a main beam of radiation in two directions along the bisector instead of in only one direction. Each of those beams for a given size of V would be a little bit broader, but of the same general character as shown here.

Mr. Brown: I will offer in evidence as Plaintiff's Exhibit 24 the directive diagram and I will attach to it as Plaintiff's Exhibit 25 the tabulation of the figures.

(Marked Plaintiff's Exhibits 24 and 25 in evidence.)

The Witness: These V-shape figures on this map of the Sayville station are the V antennas of the defendant. We [fol. 77] had an opportunity to see and examine these antennas when we were there; Mr. Darby permitted us to walk all over the station property and we saw these double V, and these single V, and di-pole arrays shown there on the map.

Cross-examination.

By Mr. Darby:

The Witness: Referring to this last Exhibit 24, where we plotted antenna No. 1, the direction of the wave being sent out is just diametrically opposite to the direction in which the antenna wires extend—i. e., from the apex to the open end; the directivity is just opposite.

I haven't had any opportunity to examine the data that you supplied with reference to all of the antennas at the defendant's station. I have not given any study to what has been marked in evidence here as Exhibit 12. I have seen it, that is just about all. I haven't been asked to check it. I didn't check for examination any of the antennas at the time I visited the station to determine what stations a particular antenna served; I believe that at that time you advised us you would supply some additional information later. We did ask some questions, and I think you answered them very frankly, but I am unable to recollect at this time just how much we were told concerning where each antenna works. When this additional information was supplied to us, it was not referred to me for study. I am not sure that I recall being told that antenna No. 7, for example, supplied Buenos Aires, Camaguey, Seattle and New Orleans; [fol. 78] it is possible you did tell us that, but I can't be sure at this time. I have no recollection personally of checking that.

I have not been familiar with the use of antennae in wireless transmission and reception since about 1918, that is, commercial use, but only since 1924. 1924 is the first time I became familiar with the commercial use of a short wave antenna for transmission or reception. I have been familiar with the commercial use of antennae for transmission or reception since 1920. The first commercial antenna I had occasion to do anything on, was at Marion, Massachusetts, in the spring of 1920. It was at the transoceanic station of the RCA on Cape Cod for transmission to Europe. It had what we know as an Alexanderson multiple tuned antenna. The antenna proper consisted of a network of horizontal wires at a height above the ground, and at intervals connections were made to ground through tuning coils.

I also referred to the British Marconi beam system of antenna. Referring, for example, to Exhibit 14, and referring to the antenna that was erected at Rocky Point, this British drawing was not sent directly to me. I have seen that drawing in connection with our work involving the erection of that antenna.

I don't know of my own knowledge that this drawing did come directly from the British Marconi Company. It was not sent directly to me.

Lawrenceville as I saw it in 1929 looked very similar to [fol. 73] that used by the Marconi Company—that is, the British beam type. In my estimation, the cost of such an antenna as that used by the Telephone Company at Lawrenceville would be very much greater than one of our Model D antennas for the same service. I believe that would also be true in the matter of maintenance; I have no definite knowledge about it. They published descriptions of this Lawrenceville antenna of the American Telephone and Telegraph Company, as erected in 1929, as I saw it in 1929. The American Telephone & Telegraph Company has issued a pamphlet describing that system there. There is a copy of it here, reprinted from the Bell Laboratories Record. There is a picture of the antenna system on the front cover. There are other pictures inside. For example, on page 2 there is a picture apparently taken from an airplane, which shows the whole station with its double row of towers.

Mr. Brown: I offer in evidence as a plaintiff's exhibit the pamphlet of the Bell Telephone Laboratories, in so far as it describes the directive antenna at that station.

(Marked Plaintiff's Exhibit 22 in evidence.)

The Witness: I have made arrangements to determine the distribution of radiation from one of the defendant's double V antennas at Sayville. That was on April 19, 1934. I and two of my assistants, Mr. H. E. Goldstine and Mr. L. L. Young, measured the directive characteristics of the antenna No. 1, as we know it, WIU, 10170 kilocycles.

This drawing, marked DNY 91, is a map of the Sayville [fol. 74] station which we saw in the office of the engineer in charge when we visited the station at Mr. Darby's invitation on August 14, 1934.

Mr. Brown: I offer that map of the Sayville station in evidence as a plaintiff's exhibit.

(Marked Plaintiff's Exhibit 23 in evidence.)

The Witness: The antenna that we measured is in the upper left hand corner of this map, and the place where we measured was on Locust Avenue, which lies off the map to the westward, and in addition to Locust Avenue we made some measurements and observations around to the north side and back of the antenna to the east. I have made a

diagram or plot showing the results of our observations of the directivity of that antenna. This drawing that you hand me is a photostat of the diagram. The mapping of the diagram was done by my assistant, Mr. L. L. Young, and he and I together have drawn the directive pattern and added some of the other material to it. Our measurements indicate that this antenna had very good unidirectional characteristics of the type we would expect to get from one of our Model D antennas, of about the dimensions shown here, and as nearly as we could check, the direction of the main beam of radiation was in the direction of San Francisco, as indicated on the map.

I said that we measured around one end and part of one side. We didn't measure all the way around because the radiations off in the other directions were too low to measure with the measuring equipment which we had available. [fol. 75] This other paper that you hand me is a tabulation of measurements made on WIU at the time that I stated previously. The points of this tabulation used to plot the main diagram have been indicated by asterisks. Some of the points not associated with the main beam have been used but not marked on this tabulation. Also, we have not plotted every reading, off to the side of the main beam particularly, because the points would be very crowded and not much would be learned from it. You refer to some of the points plotted not being exactly in the border line or margin of this beam as to any irregularity that that indicates, we found from measuring our own antennas that the measurements are more or less sensitive to the shape of the ground and local conditions around the point of measurement, so these variations from what might be called the theoretical pattern are normal for that kind of measurement. The results that we obtained are as good as we would expect to obtain on any of our own antennas.

The Court: Is that to compensate for the variation?

The Witness: We could not compensate for that sort of variation because it is due to local objects, the ground or things which we were unable to evaluate, so it is our custom to draw in a smooth curve, trying to iron out those small irregularities.

These irregularities that appear on this graph do not indicate anything negativing directivity of these antennas. In spite of those irregularities, it looks very good.

But I have always accepted it as being a drawing which came directly from the Marconi Company. I have studied the drawing in a general way and think I understand what it intends to show. I have a knowledge of the so-called British beam antenna that was installed at Rocky Point, [fol. 79] and I think I am reasonably familiar with it. It was erected at Rocky Point and completed in 1927.

This station in Massachusetts was used commercially in regular commercial practice. It had previously been in commercial operation and it was placed in operation again about the time that I was there, perhaps shortly afterwards. It had been in commercial operation even previous to the spring of 1920. It was a station taken over from the Navy and they in turn took it over from the Marconi Company, as I understand it. So it had been in commercial operation for a good number of years, but not in the same condition as it was in 1920, though. The station had been rebuilt, and before it was placed in commercial operation in 1920.

When we erected this British beam system, we had an array of wires on one side of the line of antenna masts, and another array of wires on the other side of the masts to serve as reflectors. This gave unidirectional radiation.

In the first antennas of that type erected there was trouble due to windage which would vary the distance between the arrays of wire, but this construction was used at Rocky Point to reduce that source of trouble.

According to my recollection, I said that the array of wires that were used as reflectors were adjusted so that they were substantially tuned for the operating wave length, which would mean that they would pick up considerable current and cancel radiation from the primary radiator in one direction and give it back to add, in the other. For a certain spacing there would be an optimum phase relation between [fol. 80] the wires on one side and the wires on the other, but in order to attain this unidirectional characteristic with this sort of structure, there is no specific exact phase relation required. The spacing and phase relation are dependent one upon the other and could be varied. To obtain this addition, the spacing between the array of wires wasn't critical; for 100 per cent addition in the forward direction, there was a certain spacing that was optimum.

X Q. 234. In the first system that you built up in which you said you had difficulty because of windage changing the spacing between the two wires, what was the maximum?

A. I am afraid that you misunderstood what I said, the trouble was not due to the change of the spacing between the antenna and reflector, it was due to the center of the antenna being shifted back out of line with the ends. In the system as constructed at Rocky Point, we had no difficulty due to the changing in the spacings between the antenna and the reflector. In the first system that we erected, we never had any trouble from that source so far as the matter has been brought to my attention.

The wires were tuned with respect to each other by the adjustment of the length of the individual sections in the case of the reflector and by means of lengths and size of those folded up sections in the radiator portions. Tuning is an important and necessary feature in connection with antennæ. It is perhaps putting it a little too strong, to say that it is practically indispensable in antenna transmission, but as a general proposition it is best to tune an antenna in nearly all cases.

The space relation between the radiating antenna and the reflector, where you want unidirectional transmission, is [fol. 81] very important in some devices, but not so important in connection with the Marconi antenna, as it would be with some others. In the V type antenna it is important in order to obtain maximum radiation. In the case of the horizontal parallel wire type of antenna, there are always certain relations of spacing which should be followed for optimum directivity. Those adjustments may not be critical in most cases, but they are reasonably so.

On page 1778 of the article in the I. R. E. which I personally delivered, there is shown a type of antenna with gradually diverging wires, and I said that we built at least two or three of that kind. I can't remember specific dimensions of the wires, but we used various dimensions, ranging up to perhaps six or eight wave lengths, according to my recollection. It was hoped to use the effect of traveling waves on those antennas. I do not know whether, at the present time, we could call them traveling wave antennas, actually.

On page 1778 of Exhibit 20, the arrow shows the desired direction only in one direction. The desired portion of the action and radiation from that antenna was intended to be in the direction of the arrow. If we had succeeded with that model in obtaining a true traveling wave antenna, it would not have been necessary to tune it. In a true traveling wave

antenna, you do not need tuning, but that one as shown in the figure on that page was not a pure traveling wave antenna.

I can't see any relation between the use of an impedance matching device and the matter of whether or not the antenna is of a traveling wave type. If you have a traveling [fol. 82] wave, a pure traveling wave antenna, there is no possibility of reflected waves. And a true traveling wave antenna, if it is correctly designed, can be strikingly unidirectional in radiation.

X Q. 253. I show you two lobes, and ask you if they are characteristic of a traveling wave antenna type.

A. This general character of radiation—it is not indicated here which plane they are taken in—is more or less characteristic of some of the antennas built like Fig. 3 on page 1778, which were intended to be a pure traveling wave type.

Mr. Darby: May I have these marked for identification.

(Marked Defendant's Exhibit A for identification.)

The Witness: With reference to the British beam antenna structure that I became familiar with, we used a reflector in 1926 or 1927. That is not the first time that I personally was familiar with the use of a reflector with antennae. I am not sure when I first learned of reflectors, but my understanding is that Marconi had used them quite a long time before.

In the reflector that we used of the British beam type, I do not believe I would say that the reflector was virtually a duplication of the antenna but spaced from it, that is, from the radiator antenna; there was quite a large difference in the structure. It was excited only by radiation from the radiator portion. The term "parasitic excitation" has been used to describe that.

I cannot say for certain when I was first familiar with the [fol. 83] use of a spaced reflector of any type. I would judge that soon after I began doing active radio work in 1920, I must have learned of Marconi's spaced reflector of the parabolic shape. As to when I was first familiar with a reflector which was separately excited, that is, fed with energy from the transmitter, so far as I can recollect, now, Carter was the first one to suggest such a thing to me, and I think in 1921.

In order to obtain unidirectional characteristics, it is necessary to have a spacing between the antenna and the

reflector which is a multiple of a quarter wave length, and phase relation differing by 90 degrees. When I say I desire unidirectional radiation, I mean that the reflector is spaced in a direction or in the direction in which it is desired to radiate. I have known that, in connection with the fed reflector, since Mr. Carter told me in 1921, or thereabouts.

X Q. 269. In this same article of yours, Exhibit 20, on pages 1824 and 1825, you say, "Unidirectional characteristics is obtained by using a radiator system in the usual space and phase quadrature relation." When you say "the usual space and phase quadrature relation", you are referring to the principle we have just covered that you have known since 1921?

A. That is the space and phase relationship we had reference to, yes.

When we are using what is sometimes known as the parasitic reflector, it is not absolutely necessary that the same relation be obtained between the two antennae: for example, in the case of the Marconi beam, it is only necessary that the phase relation of the reflector be such as to cancel [fol. 84] radiation which would tend to pass through the reflector, so that still quite a good directional characteristic can be obtained without carrying out this exact relation that I speak about here. The best relation is not exactly the relation as expressed, the quadrature relation, but approximately.

When we speak of space quadrature relation, we mean that the spacing between corresponding points of the radiators is a quarter wave length or multiples of a quarter wave length, measured in the direction of desired radiation. When we speak of quadrature phase relation, we mean that the timing of the current in the corresponding elements of one radiator is a quarter-cycle or 90 degrees different from the timing of the currents in the other radiator.

X Q. 274. Now, in your direct examination, you described at length and amplified your description by referring to Exhibit 22, an antenna of the American Telephone & Telegraph Company. That, of course, is not the only antenna of the American Telephone & Telegraph Company that you are familiar with, is it?

A. It was the only one I was familiar with at that time in 1929, but I have heard of another antenna since that time.

I have more than heard of another antenna; I have seen models of it and had it described to me by telephone engineers. They call it the Bruce antenna. It is a short wave antenna. I can't remember now when I first saw or heard this antenna described to me. 1929 would be too early I think. It was probably some time after 1929, I couldn't place the date at this time without checking it up.

[fol. 85] X Q. 280. I rather gathered from your testimony that you desired to draw a picture of what prior to the commencement of this suit had been used commercially for short wave transmission, that was your purpose, wasn't it?

A. Well, I had no purpose; I only answered the questions that were asked of me. I haven't any purpose at all. I personally had no purpose in not referring to this so-called Bruce antenna. I know now of the existence of the Bruce antenna in commercial use. I do not know how soon after 1929 I knew of it. I may be able to find some idea of that, but I can't place the date accurately now.

As I understand this type of antenna, it is made up of the equivalent of two V's arranged in the shape of a diamond. And at the one end energy is applied to the antenna from a transmitter or transmission line, and at the other end a resistance or loss device is inserted that prevents reflections back along the antenna. It has also been used, as I understand, without that resistance at the end.

Referring to Exhibit 24, which is the directive pattern that I prepared at the defendant's station, the pattern that I have drawn was effected by measurements that we made outside of the property on which the antenna was erected. The line on the diagram "Limit of Plotted Measurement" continued out, does not show the limit of territory that we covered in making the measurements; we covered measurements around the whole—or perhaps, I should say, observations around an angle of about 240 degrees, as I recollect we attempted to take measurements out in this direction, that is to the right of the edge of the paper, but the radiation was extremely low, and there were indications [fol. 86] that what we did get was largely due to wires in the vicinity of the measurement, so that the only definite conclusion we could draw was that radiation in that direction was very small. We assumed that there were a number of side lobes which our readings or observations, made

at a considerable distance from the antenna, and outside of the property, indicated were present. So our readings and observations led us to the conclusion that there were side lobes; also we would naturally assume that, from our own experience with the theoretical and measured directive characteristics of similar antennas. Aside from measurements that we obtained from the side lobe which led us to that assumption, they were not of sufficient strength to lead us to believe they were used commercially to reach New Orleans; we did not form any conclusion about their having been used.

Our instrument by which we made those measurements was in an automobile and the antenna, which picked up the energy for us to measure, was at a height of perhaps 15 feet from the ground. And that is substantially true of all the measurements we made in the automobile. As to what I mean by "substantially true", so far as I can recollect, all of the measurements made to form the basis of that curve were made with the one height of 15 feet, but our antenna was adjustable to make it possible for us to drive under limbs of trees and things of that sort. It was more likely 15 feet than within a range of 10 to 15 feet, I think.

[fol. 87] Redirect examination.

By Mr. Brown:

The Witness: On this matter of the measurements, in connection with Plaintiff's Exhibit 24, our measurements—those that are plotted—were made along Locust Avenue. Whatever the considerable distance that was referred to by Mr. Darby was, the measurements were made along Locust Avenue across the beam. Our observations were clear around the bisector of the angle in both directions; as I said before, I think we covered an arc of about 240 degrees.

I was asked whether in a true traveling wave antenna, there is possibility of reflection on the antenna; there might be reflection on the transmission line to such an antenna.

The wave length used at the Marion, Mass., station was of the order of 12,000 meters, or about 40,000 feet. I believe that is something like seven or eight miles. The whole portion of the wires of that antenna starting from

the point where the wires were connected together at the building and including the leads going to the top, and the top itself, were all a portion of the radiating part of the antenna. The length of the upright or substantially vertical part that went up to the horizontal top of that antenna was perhaps on the order of 400 feet. I think the length of the horizontal portion was about three-quarters of a mile; I do not recall the dimensions in meters.

After RCA had purchased the British beam antenna for Rocky Point and Riverhead, they never bought any others; those were the only ones we ever bought.

That antenna at Marion was substantially not directive.

[fol. 88] Mr. Darby: At my request, Mr. Blackmar has kindly given us a list of each of the claims of each of the patents in suit, which recites: "As at present advised, plaintiff will contend that claims of the patents in suit are infringed by defendant's antennas as follows:

"Lindenblad No. 2:

Claims 9, 10, 19 and 23	By all V antennas
"Carter No. 3.	
Claims 1-4, 28, 38 & 40	By all double V's
"Claims 10, 12	By Ant. No. 8
" 15,	By all V's
" 16,	By all double V's
" 34-36	By No. 2 (orig.), by 3 (rebuilt), and by No. 8."

John V. L. Hogan, called as a witness in behalf of the plaintiff, being first duly sworn, testified as follows:

Direct examination.

By Mr. Blackmar:

The Witness: My name is John V. L. Hogan; my residence is in Forest Hills, Long Island; and my occupation is that of consulting engineer.

My first interest in radio was as an amateur in 1905 or 1906, or thereabouts, perhaps earlier. In 1906 and 1907, I was laboratory assistant to Dr. Lee De Forest, in his development work of wireless telephony and the vacuum tube. In 1908 to 1910, I attended the Sheffield Scientific

School, taking an electrical engineer's course, and specializ-
[fol. 89] ing in physics and mathematics, but I did not complete the course since I left in the middle of the junior year, 1910, to join the National Electric Signaling Company at Brant Rock, Massachusetts. That was Professor Fessenden's radio organization. I remained with that company and its successor, the International Radio Telegraph Company, until 1921.

With the Fessenden organizations, I began as a telegraph engineer, and my work included the design and the investigation and the operation of many types of radio transmitters, radio receivers, antenna systems and accessory apparatus. With the organization, I became chief research engineer, and finally manager, and during that period of about ten years, I handled investigation, design and measurement problems in a large part of the radio field.

A considerable portion of my work had to do with the transmission of signals, the measurement of signal intensity, the effect of changes in antenna design on signal propagation, and in general studies of the radiating systems as well as of the apparatus connected with the radiating systems.

Since 1921, I have practiced as a consulting engineer, working for broadcasting stations, radio set manufacturers, the Federal Communications Commission, and its preceding body, the Federal Radio Commission, and others.

My work in connection with my consulting practice has included studies of apparatus, both transmitting and receiving, of antenna systems, both directive and broadcasting types, and of accessory apparatus.

[fol. 90] I am a fellow and past president of the Institute of Radio Engineers, and a member of its Board of Directors, a member of other technical societies, including the American Institute of Electrical Engineers, the Acoustical Society of America, the Society of American Military Engineers, and some others.

I have presented a number of technical papers, written a number of technical articles on radio matters. I have contributed to books on radio in conjunction with other authors, I have written one myself; I have made a number of inventions in the field, and, on the whole, my experience has been, over this period of about thirty years, more

directly in the practical field than in the theoretical field, although I have studied the theories involved in all of this work and used, as far as possible, the theories as a tool or a basis for the practical applications of the work.

The Fessenden Company during the early years was entirely an experimental organization. The experiments, however, were full scale experiments, if I may characterize them in that way, that is to say, at Brant Rock, for example, we had a transmitting station, with a 400 foot tower, which was entirely competent to transmit, and did transmit, signals over trans-Atlantic distances. All of the operations of the company, therefore, were on a commercial scale, though they were not used in those years, for the transmission of messages for pay.

In the later years, from about 1919, the company operated a ship to shore commercial radio service and had a number of coastal stations which were engaged in the transmission and reception of messages for pay.

[fol. 91] Q. 4. Will you please outline briefly a radio communication system, with the fundamental elements of such a system?

A. In general terms, a radio communication system is like any other communication system. All of them are fundamentally alike, because in every case the object is the transmission of signals representing an intelligible message, from one point to another point.

The transfer of those signals through whatever system is used represents the act of communication, of course. Every one of these systems, whether it be the wire telegraph or the ordinary telephone or the radio system, can be looked on as having three fundamental divisions, the first, a transmitter, the second, a medium extending outward from the transmitter, and the third, a receiver connected to the transmitter by that medium.

The functions of those three divisions of the system correspond, generally speaking, to the words "In", "Through", and "Out", the transmitter placing the intelligence into the system, the medium carrying it through, and the receiver taking it out for use by the receiving operator or the person at the distant end.

Although radio is like other communication systems in those general respects, it differs, of course, both as to the

medium that it uses and as to the form of the apparatus used in the transmitter and the receiver.

For example, in a simple wire line telegraph, the transmitting element may be only a telegraph key and the battery which supplies the power. The medium of communication is the wire, the telegraph line, and perhaps the ground [fol. 92] used for a return circuit, or perhaps a second wire. The third element, the indicator or the receiver is the telegraph sounder at the receiving end.

Now, in this ordinary wire telegraph, those three elements are tied together, so that the mechanical motions up and down of the telegraph key at the transmitter end are reproduced by the up and down motions of the sounder at the receiver end. The Morse code is used to represent the intelligence by combinations of dots and dashes, and thus the message is transferred.

In the case of a radio there is no tangible medium between the transmitter and the receiver, no medium other than ground, at least, and the waves with which we are concerned, are considered as traveling through the space above the ground. The medium generally accepted as carrying the radio waves is called the ether of space. There is some dispute as to whether or not there is such a thing as ether, but if there is not an ether, there is something else, which we might as well call ether, so I think that dispute need not bother us.

The radio transmitter is an apparatus that is designed to impress upon this ether of space a form of wave or electro-magnetic disturbance that will travel from the ending point through space to the radio receiver.

The radio receiver is another form of electrical apparatus. It is designed so it can abstract from space a certain amount of this signal energy, this wave energy, and can convert into a signal indication.

The controversy here is concerned with the radio transmitter. More specifically it relates to the arrangements, the [fol. 93] structures by means of which the electrical generating apparatus at the transmitter is enabled to impress upon the ether of space these energies or this energy which is represented by the electro-magnetic waves.

The specific portion of the transmitter with which we are concerned is, generally speaking, the antenna and the connections to it, rather than the details of the transmitting or receiving apparatus, and consequently, I think there is

no need to go into the details of either the transmitting or the receiving apparatus here.

Q. 5. Will you please describe the operation of a simple radio transmitter or transmitting system, with particular reference to what is involved in the present suit?

A. I have made a sketch marked "Elementary Diagram of Radio Transmitter," and it shows, by the usual symbols, the four principal parts of any radio transmitter. The first is marked 1, and is a generator of high frequency alternating currents.

The second part, marked 2, is a signalling device of some kind, and here I have shown it as a telegraph key, the simplest possible form of signalling device.

The third element, here marked "coupler", represents whatever means may be used for transmitting the high frequency current made by the generator over to the antenna or radiating system.

And the fourth part is the radiating antenna wire system, here marked "Antenna", but when taken as a system including not only the radiating wires, but the lead-in to the transmitter building and the ground connection.

With a transmitter of this sort operating, the generator [fol. 94] gives off a sustained stream of high frequency electrical impulses. When the telegraph key is pressed down, the circuit of the generator is completed, so that the energy from the generator may flow through the generator circuit and through the transformer or coupler, perhaps I should say, across the transformer or coupler, to the antenna system. So that the operation of the key turns on and off the high frequency current in the antenna wires. That is because when the key is up, the generator circuit is broken and no energy is applied to the coupler. By pressing the key for short and long intervals, the usual dot and dash signals are formed, those being represented by short and long streams of currents, high frequency currents, in the antenna system.

The antenna is adjusted or tuned by selecting its size, or by compensating for its constants by the size of the right-hand coil in the coupler 3, so that a substantial amount of high frequency current flows up and down in the antenna system, whenever the telegraph key is depressed, and the circuit from the generator to the antenna is thus completed.

The passage of this high frequency current in the antenna wires causes the radiation of radio or electromagnetic waves, and the greater the antenna current is, the more current there is in the antenna, the more power will be radiated in the form of waves from a given antenna system. As a matter of fact, the amount of power which is given off by an antenna increases as the square of the current in the antenna system, so that if the current is doubled, the power is quadrupled, and so on.

[fol. 95] I have spoken of the generator as producing high frequency impulses. It would be more nearly exact to say that the generator produces electro-motive result or voltage; that is, the force which tends to drive an electric current through an electric circuit, the current being the force of that electro-motive force applied to a circuit which is capable of carrying electric currents.

Perhaps I should also say that when that voltage is uniform and direct, always tending to produce a current in one direction through the circuit, the current which results is a unidirectional or direct current, a continuous current. But here we are concerned, almost entirely with cases where the direction of the voltage or electromotive force produced by the generator alternates. It is first in one direction and then in the other, and consequently gives rise to a reversing current through any of the circuits, so that the direction of current flow through the circuit reverses, as the voltage direction changes.

Q. 6. What would happen if the generator in this sketch were a direct current generator?

A. There would be no current flow through the circuit after the condenser marked C had been charged, because that is an alternating current circuit. If the condenser C were left out of the circuit, there would be a flow of direct current in one direction, through the coil at the left of the coupler marked 3, but after that current had attained its steady value, there would be no transfer of energy across from one transformer coil to the other, because the transformer can only transfer changing currents, such as are represented by alternating currents.

[fol. 96] Q. 7. And what happens if you apply direct current to an antenna?

A. You get only enough current to charge the capacity of the antenna, and then the condition is fixed; no more current flows until there is some change in the system.

Q. 8. Is there any radiation under these conditions?

A. No, except possibly a slight radiation during the time of charging; there is no radiation of useful wave lengths.

Q. 9. Will you continue with your answer?

A. With respect to these alternating currents with which we are concerned here, we should consider the fact that alternating currents generally include to and fro motions of current in circuits over an extremely wide range of frequencies.

For example, in power supply, lighting and traction systems, the current changes its direction in the circuits a matter of 15 or 25 or 60 times per second, and consequently the current is spoken of as a 15 cycle or a 25 cycle or a 60 cycle current, because a cycle is a complete change of direction, and the number of cycles per second, usually simply spoken of as the number of cycles, defines the frequency or the rate of change of direction of the alternating current.

That type of alternating current used in power practice is, so to speak, at one end of the range of currents considered in electrical engineering. At the other end we have very high frequency currents, such as are used in radio. Even those extend over a wide range of frequencies, and in radio we have radio frequencies of antenna current as low as ten or fifteen thousand cycles per second, and as high as many millions of cycles per second. It seems so strange to speak of a 15,000 cycle current as low, because that is [fol. 97] actually changing its direction of current flow 15,000 times in each second, but it is at the low end with respect to these radio frequency currents, because the highest frequencies change their direction millions of times in one second.

Intermediate to the power frequencies and radio frequencies, there are audio frequency currents, used largely in telephony and in radio where the frequency corresponds to the range of frequencies in a sound, audible sound, perhaps 15 or 20 cycles at the low end, to perhaps 10 or 12 or even 15 thousand cycles per second at the high end. Those currents we are not particularly concerned with here.

I spoke of a generator as producing an electromotive force or voltage. The value of that is measured in the practical electrical unit called the volt. The higher the voltage, the more the volts produced by any generator, the greater the electromotive force, or the greater the tendency to produce current in a circuit. The amount of current in an electrical circuit is measured in the practical unit of amperes, or if very small currents are involved in fractions of amperes; for example, one thousandth of an ampere is known as a milliampere. Here we are concerned with very large currents of the order of amperes.

What determines in the simple case the amount of current through a circuit is the voltage or force applied to the circuit and the property of the circuit called its resistance, the resistance being the property which tends to prevent the flow of current. That is measured in ohms, and the simple law is that the current through the circuit measured in amperes, equals the electromotive force applied to the cir- [fol. 98] cuit and measured in volts, divided by the resistance, so that the higher the resistance, obviously the less the current for a given voltage.

Q. 10. Is that resistance analogous to friction in a mechanical system?

A. That is correct.

Q. 11. And the voltage is analogous to pressure?

A. Yes, or force.

Q. 12. And the current is analogous to the amount of energy that may be flowing in some form, such as the amount of water flowing through the pipe?

A. Yes, it is not analogous to the amount of energy, but it is one of the components of energy, it might be analogous to the number of cubic inches of water per second passing a given point in a pipe, that would be analogous to an ampere.

Going back to this elementary diagram of a radio transmitter, I should point out that both of the circuits shown, namely, the circuit of the generator, and the circuit of the antenna, contain electrical units or elements having two other important circuit constants. With respect to the generator circuit, the parallel line symbol marked C represents the condenser which has the property of capacity or the ability to store an electric voltage or an electric charge. The coil indicated by the wavy line at the left of the coupler

3 has the electrical property of inductance, which is associated with the ability to set up a magnetic field due to the current passing through the coil or conductor.

Those same two properties of capacity and inductance are present also in the antenna to ground system at the right of this sketch, the inductance being contributed principally by the right-hand coil of the coupler, and the capac-[fol. 99] ity being contributed principally by the group of wires constituting the radio system, taken as one plate of the condenser and the ground below them taken as the other plate of the typical condenser which represents the property of capacity.

For any particular frequency in a circuit having capacity and inductance, the two may be balanced against each other so their effects cancel out, and broadly speaking, in that condition the circuit is said to be tuned. In general, when a circuit is tuned to a specific frequency, it will carry a maximum current for the amount of electromotive force that is applied to it, and consequently, it has been customary for years to tune radio frequency circuits in order to increase the flow of current in them.

Q. 13. Can you give a simple analogy in a mechanical system of the equivalents of inductance and capacity?

A. Yes, I think the simplest analog is that of a spring pendulum in which a weight is supported by a helical spring. The weight has mass which corresponds in the mechanical sense to inductance in the electrical sense; the spring has flexibility, which corresponds generally to the effect of capacity. Any system having the spring and mass elements when set into motion and left alone will have a tendency to vibrate at a particular frequency, and if it is driven by an external force, it will vibrate best when the external force has that natural frequency of the system.

The electrical case is quite closely analogous in that if an electrical circuit constituted principally of elements having capacity and inductance is shocked or excited, it will tend to vibrate at a certain frequency, which is called its natural [fol. 100] frequency; and if that circuit is driven by a periodic force from the outside, in general, it will vibrate most effectively, or in other words, develop the most current when the frequency of the driving source corresponds to the natural frequency of the circuit.

There are some minor effects produced by resistance which make the analogs strictly and in detail not applicable, but I think they give a graphic picture of the system.

Q. 14. And in the mechanical system, may the nature of the free period of vibration be altered by changing the weight or the mass of the weight or changing the elasticity of the spring or by both?

A. That is correct, and the same thing holds true in the electrical system; the resonance frequency, the frequency to which the system responds best, may be changed by varying the amount of inductance or the amount of capacity or both in the electrical circuit.

Q. 15. That completed your previous answer?

A. Unless there are other items that you would like to have me explain in further detail in connection with this sketch. I might point out that the patents involved in this suit have to do with the antenna system and the means for transferring electrical power from the generator to the radiating antenna system and not with the details of the generator or of the signaling system, that is, the key, and so on, shown in this diagram.

Mr. Blackmar: I offer the sketch in evidence entitled "Elementary Diagram of Radio Transmitter".

(Marked Plaintiff's Exhibit 27 in evidence.)

[fol. 101] Q. 16. Will you please give a simple outline of what radio waves are and how they are set up and propagated?

A. The simplest way to get an idea of what radio waves are is to consider them in comparison with other types of waves, which other types appeal directly to our senses. For example, we are not equipped, humanly speaking, with antennas that will respond to radio waves. Radio waves are passing through and by us all the time in these days of broadcasting, but we have no way to tell it in our bodies.

On the other hand, we do have receivers of sound waves in our ears, in the auditory system, tied in with the brain, and we have receivers of light waves in our eyes and the nervous system connected to them.

Sound waves are mechanical vibrations of any medium such as air. They will be produced by the vibrations of any moving body so long as those vibrations have frequen-

cies in the range of audio frequency, of which I spoke, extending from perhaps 16 vibrations or cycles per second up to 16,000 vibrations per second as the upper limit. So the prongs of a tuning, of a vibrating tuning fork, for example moving back and forth within that range of frequencies or at some frequency within that range, perhaps the frequency of c, 256 vibrations per second, those prongs are capable of giving off sound waves. What they do is actually to strike molecules of air in which they are immersed and those molecules of air collide with others, so that the successive collisions produce a wave extending out to greater and greater distances from the tuning fork and conveying sound energy from that tuning fork in all directions from it [fol. 102] as a source and at the speed or velocity which is characteristic of sound in air, namely, about 1100 feet per second.

When some of the vibrating air particles strike the ear drum they shake it or cause it to vibrate and produce the sensation of sound.

In the case of light the waves are not mechanical but are electromagnetic. They are conveyed through this medium which we are calling the ether of space. They have much higher frequencies than sound waves, and they travel at a much higher speed. The flame of a lighted match or a candle, for example, will cause space vibrations, electromagnetic vibrations in space that have a frequency of the order of perhaps five hundred million million cycles per second, that is to say, five hundred trillion cycles per second. Those vibrations react on the ether of space around the flame and they cause electromagnetic waves of that tremendous frequency. Those waves travel outward from the source of light at a very high speed, the speed being about 186,000 miles per second instead of the relatively slow 1100 feet per second characteristic of sound.

Q. 17. How fast in the metric system?

A. Three hundred million meters per second. The waves when they strike the eye of the observer stimulate its mechanism and produce the sensation of light. It is an interesting thing that the color sensation depends on the frequency of the vibrations. For instance, if the frequency is increased to about 700 million million cycles, violet light is produced as the sensation; if it is reduced to about 450 trillion, or million millions, of vibrations per second, the light sensation is toward the red end of the spectrum and

here we come to the analogy or the connection with radio [fol. 103] waves because if the frequency of these light waves, which are electromagnetic in character, is reduced below the lowest value that produces the sensation of red color, the waves still continue, the eye cannot see them, but they become thermal waves, or heat waves, infra red waves, which can be detected to a certain extent by, for instance, reaction upon the human skin, or upon mechanical or chemical detectors of infra red rays.

Now, the radio waves that we are considering here are of the same kind as these light waves and heat waves, but their frequencies are still lower, really very much lower. The range of electromagnetic waves used for radio, instead of being measured in millions of millions of vibrations per second run from several millions on down to 10 or 15 or several tens of thousands per second. However, they do travel at this same speed of 186,000 miles per second and they are sent out from the radio antenna in much the same way as light waves are sent out from a flame.

The radio waves are produced by the rapid surging to and fro in the antenna wires of the high frequency currents that those wires carry, and the radio waves in the spaces around the antenna have the same frequency as the frequency of the current in the antenna wire that sets the waves up.

Going to the other end of the system, when the radio waves in space strike an electrical conductor, such as a receiving antenna wire, they produce in that conductor high frequency electrical currents having the same frequency as had the original current and as had the waves. Those currents produced in the receiving wire, when they [fol. 104] are let down to the receiving apparatus, used to operate a radio receiver or detector.

Q. 18. What is the relation between wave length and frequency and what values of each are used in radio?

A. In radio waves, and really in all other waves, there are two factors that are important. One is the frequency of the wave, to which I have already referred, that is to say, the number of vibrations per second, and by that I mean the number of complete vibrations per second, a complete to-and-fro swing of the wave, in other words, the vibration represented by a complete cycle of operations in the wave; the second factor is the wave length, and that is represented by the distance measured between two correspond-

ing points in the wave as it is set up in the conveying medium. For example, in water waves, the wave length is measured by the distance between successive crests of the waves or by the identical distance between any other two points on the wave which are at the same part of their swing.

Now, a wave progresses a distance equal to its wave length in one cycle and since it makes a certain number of cycles per second, which number of cycles we call the frequency of the wave, it is quite clear that in one second it must go a distance corresponding to the wave length multiplied by the number of vibrations in one second. That distance is then the speed or the velocity of the wave, and it follows, since the wave length times the frequency equals the velocity, that if we want to determine the wave length and know the velocity and frequency, we may simply divide the velocity by the frequency in order to obtain the wave [fol. 105] length, or, if we know the wave length and the velocity, we may divide the wave length into velocity in order to find the frequency of any particular wave.

In radio it is customary to measure the wave lengths in meters, a meter being about three inches more than one yard, or 3.28 times the number of feet. The wave frequency in radio is often measured in cycles, but more customarily in kilocycles or thousands of cycles per second. Therefore the velocity for radio waves is usually given in the terms of meters which are used for measuring wave length, and as I have said, works out, instead of 186 thousand miles per second, as 300 million meters per second or 300 thousand kilometers per second, the three values being the same and being the same as the velocity of light.

The practical beginnings of radio were in the late 1890's or about 1900, and in its first decade, up to about 1910, the waves used had wave lengths generally speaking of the order of several hundreds of meters, for example, 300 meters, 600 meters, or even 1000 meters.

In the second decade, which we can take as 1910 to 1920, there was a tendency to use, in addition to these waves of hundreds of meters in length, waves considerably longer. For example, waves were used up to 10,000 or 15,000 meters in wave length, even as high as 20,000 meters. Remembering that a mile is about 1700 meters, these longer waves are seen to run up to about ten miles in wave length.

About 1920, and in the third decade, the waves used began extending in the shorter direction to 200, 150 meters. Such [fol. 106] short waves had been used, of course, in the very early days of radio and during the war also, but those uses were not over great distances. One important reason for that was that powerful and dependable short wave transmitting apparatus had not been developed at the time of the World War.

I have made a little chart giving the relation between wave lengths and frequencies for a number of these typical values, and in each case have indicated both the number of cycles and the number of kilocycles in the frequency, and also the wave lengths in meters. These two measurements of the same wave disturbance in radio are interchangeable because the velocity is fixed, and in each case it represents simply frequency equal to velocity divided by wave length or the other side up, as I have explained.

Q. 19. With the result that the longer the wave length the lower the frequency?

A. That is right.

Q. 20. And vice versa?

A. That is right, the higher the numerical value of frequency the lower the numerical value of wave length, or the other way up.

Q. 21. And the only difference between the second and third columns is that the second column is a thousand times greater than the third column in each case?

A. That is right, because a kilocycle represents 1,000 cycles.

Mr. Blackmar: I offer the chart in evidence.

(Marked Plaintiff's Exhibit 28 in evidence.)

Q. 22. Will you please describe simple forms of trans- [fol. 107] mitting antennas and refer to the general characteristics of radiation of radio waves from them?

A. Yes. In the little sketch of Exhibit 27, that is, the elementary diagram, the antenna that is symbolically indicated there is the classical Marconi antenna, that is to say, the vertical, connected to ground at its lower end. The radiation from such a vertical antenna spreads out in all directions over the ground surface and travels along the surface of the ground. Of course, there is radiation at upward angles from the ground, but I am concerned at the

moment with the principal radiation which is along the ground surface.

That Marconi antenna has been the typical antenna used in commercial radio stations and in broadcasting stations for years, sometimes in the form of a single wire and often in the form of a multiplicity of antenna or aerial wires.

When the antenna masts or towers to support the upper end of the vertical wire were not tall enough so that the vertical wire alone would be large enough for effective radiation with a certain wave length, it has been customary to increase the electrical length of the system without increasing its physical length by connecting what Lodge called a loading coil at the ground end of the antenna wire, or by adding additional horizontal wires at the top of the antenna, the vertical portion, so making what has for a long while been called a flat top antenna. The coil of which I spoke added principally inductance to the antenna circuit. The flat top wires added principally capacity to the system. The addition of either of those tended to tune the antenna to a lower frequency because the larger the capacity or the larger the inductance in a circuit, the lower its resonance [fol. 108] frequency, and consequently, to make it better adapted to longer waves than would be the simple vertical wire.

The horizontal capacity wires at the top of the antenna, while increasing the electrical capacity of the antenna circuit in general, did not contribute to the practical radiation or in any event did not contribute substantially to that, the radiation being regarded as principally from the vertical section of the antenna.

The usual antenna had a vertical section which was considerably shorter than a quarter of the wave length, because, as your Honor can see, if even as short a wave as 300 meters were being used, a quarter of that would be about 75 meters or more than 200 feet, and it is difficult and expensive to get aerial structures of such great height. For still shorter waves and particularly in some of the more recent broadcasting applications, a single vertical wire, one-quarter of a wave length long, has been used as the antenna and that is strictly the classical Marconi form without horizontal conductors added to it, for example.

Now, when wave lengths less than 100 or 150 meters came into wider use in the early twenties or thereabouts, another

type of antenna became important in the art. That is the so-called half wave di-pole, and the half wave di-pole is simply a pair of quarter wave length wires placed end to end in a straight line so that the overall length of the pair is one-half wave length, there being one-quarter wave length on either side of the central point, which is where the energy is fed into the system.

Such a pair of wires was usually supported at some distance above the ground and might be turned either verti- [fol. 109] cally or horizontally or at some other angle.

A half wave di-pole of that sort, of course, would have extreme dimensions if the wave were long, but if the wave were of the order of 50 meters, say, roughly, 150 feet, the total length of the di-pole would only be 75 or 80 feet, which is not too much to build into reasonable antenna structures.

A pair of quarter wave length wires placed end to end and constituting a di-pole in that way when fed with the energy from the transmitter at the central point has a very real practical advantage in that it is able to radiate a large proportion of the power which is delivered to it. Another way of saying that is that the radiation efficiency of the di-pole is higher. By that, one simply means that the percentage of the power, of the total applied power, which is converted into radio waves, is a large percentage. In any antenna, as I pointed out, the power is proportional to the square of the current flowing in that antenna measured at a point of maximum current. It is also proportional to a factor called the radiation resistance. That is a measurable quantity which represents the opposition that the current strikes in setting up radio waves. If the radiation resistance of a radiating system is a large proportion of the total resistance of that system, it follows that the remaining loss resistance making up the total is small. Consequently, the proportion of radiation to losses is in favor of radiation and the system is efficient.

Q. 23. Mr. Hogan, in connection with radiation resistance, I have been more or less brought up to consider that [fol. 110] resistance was something you did not want. Is that so with respect to radiation resistance in an antenna?

A. Resistance is something you do not want if it represents a conversion into something you do not want. For example, resistance converting electrical power into heat

is certainly something you do not want in the wires going to an electric light, but if at the end of those wires you have a filament of an incandescent lamp, or, better yet, if you have a toaster, the resistance represented by that filament or the heater elements in the toaster is an important and useful part of your system.

Now, that same thing is true with respect to radiational resistance in measuring the useful effect, because it is the thing that you work against in producing the effect that you want, namely, the thing you have to utilize, radiational resistance, in order to get effective radiation. That, perhaps, is a crude and popularized way of describing radiational resistance, but it is strictly correct to say that the amount of power radiated into space depends upon the square of the current in the antenna system, and is proportional to this factor which we call radiational resistance; consequently, the higher that value for a certain amount of current, the more power will go into space. Similarly, the higher that factor is in proportion to the total resistance of the antenna, which is made up both of radiation resistance and unwanted or loss resistance, the higher the efficiency is of the radiating system.

That is why the di-pole was particularly good. It had and has a radiating efficiency such that well over 90 and often as much as 99 per cent of the power applied to the wire was converted into radiated waves; whereas, with the older [fol. 111] forms of antenna, such as the simple vertical wire, which usually included a tuning coil at the base, as I have said, and horizontal extensions at the top, a radiating efficiency of ten per cent, fifteen per cent, was considered high. Consequently, the rest of the power, the other 90 per cent or 85 per cent was used up uselessly in heating the ground, the conductors, the coils, and whatnot, and did not produce useful waves.

I think those two types of antenna, that is to say, the simple vertical Marconi antenna, with the ground connection, whether modified by the flat top wires or not, and the simple half wave di-pole, whether horizontal or vertical, are representative of the simple forms of transmitting antenna. And I think I have pointed out the general characteristics of radiation as to the amount sent out by each.

Perhaps I should go further in saying that with the Marconi antenna, constituted simply of vertical wires, or with the half wave di-pole arranged vertically above the ground,

the principal radiation with which we are concerned, extends in all directions around the antenna, travels out over the ground surface, north, each, south and west. The di-pole antenna does not radiate endwise, so that if the wire is vertical, and one is immediately above it, as, for example, in an airplane passing over it, strictly, practically no signal would be received. There are always some stray radiations, so that no one ever gets an exact zero except theoretically, but there is a point where there is in effect no practical radiation directly in line with the wire. That means if the vertical di-pole is turned so that its wires are horizontal, the principal radiation will be perpendicular [fol. 112] to the wire and not off its ends in either direction.

Q. 24. I think it might be helpful to refer to Fig. 1 of the first Lindenblad patent, in connection with radiation from a di-pole?

A. Yes, Fig. 1 of Lindenblad patent No. 1,884,006, is an approximate representation of the distribution of the field around a di-pole wire, which is marked 2 in this figure; that is to say, the vertical line in the center represents the half wave length wire itself, and the two circular figures or lobes on either side of that wire represent the distribution of the field intensity around the wire in a plane containing the wire.

There is a similar "figure 8", in any plane rotated around the wire. This line shows the intensity of the radiation in any particular direction from the center of the antenna system by indicating how far a line would be drawn in any particular direction, if that line had a length proportional to the field intensity delivered in that particular direction. Thus we can say that a line extending directly to the right would go all the way to the point marked 4, and represent a maximum intensity of radiation in that direction. On the other hand, a line in the direction of 45 degrees upward would strike the circle before the line was as long, and consequently it will be reduced, there will be reduced intensity of radiation in that particular 45 degree direction.

Going on to the limit, if the line were extended vertically or in the direction of the wire itself, it would strike the circle at the beginning, so to speak, and would have no length, indicating theoretically no radiation in the direction of the wire.

[fol. 113] Q. 25. Will you please explain the difference between point-to-point communication and broadcasting, as applied to radio communications?

A. The field of radio communications is divided, roughly, into those two categories, point-to-point and broadcasting. Of course, there is some overlap, as there usually is when one attempts to divide a large field into two parts, but that is an overlap as between the service rendered by certain stations, rather than the concept of the two types of communication.

Point-to-point communication involves the definite location of the transmitter and of the receiver. For example, with the transmitter in New York, and the receiver in San Francisco.

In radio, such point-to-point communication takes advantage of the fact that there is a free medium, the ether of space of which we have spoken, that connects any two given points where radio stations may be located. But the object of point-to-point communication, technically speaking, is the delivery by a particular radio transmitter of the strongest possible signal at, or as received at, a certain particular point, the receiving point.

Now, radio broadcasting is generally taken as the distribution either of information or entertainment or any other type of communication to a large number of scattered listeners. Of course, broadcasting, properly speaking, may also include the transmission of messages to ships or to aircraft or police automobiles, because one does not know the exact location of any of those things at a particular time, and because one may wish to send the same message to a number of them in different locations at the same time.

[fol. 114] Now, broadcasting uses, in addition to the natural economy of the free medium, so to speak, the fact that that medium provides a radial distribution, that is to say, a distribution in all radial directions from any particular transmitting point; and thus permits the waves to cover a wide area, surrounding any particular transmitting point.

The two types of service are really in strong contrast. One can see that broadcast radio must deliver signals over a wide area, a substantial area in order to be effective, whereas in point-to-point communications, it is only necessary to deliver the radio signal to a specific receiving point in a definite location.

In broadcasting, the service is more effective as the signal is spread out over more and more area, and as the intensity of signal throughout the whole area is built up to large values.

In point-to-point communication, the more powerful the signal is at the specific receiving point at which one is interested, the better the service is.

Q. 26. What is horizontal directive radiation and what is its utility in radio communication?

A. We considered briefly an example of horizontally directive radiation in discussing the di-pole arranged with the wire horizontal, because in that instance, the radiation along the surface of the ground extends most effectively in the two directions perpendicular to the direction of the wires, and does not extend in the direction of the ends of the wires. If the di-pole is vertical, we can imagine its radiation as spreading out in an approximately circular distribution over the earth's surface.

The radio waves in the case of the vertical di-pole then correspond generally to the distribution of the rays of [fol. 115] light from a light-house traveling out in all horizontal directions. That, of course, is the best distribution for broadcasting, because the signals can be heard in any direction measuring horizontally from the transmitting station, and they get out there with equal force in all directions, and they do not weaken in force with any specific direction, but only as the distance from the transmitting station is increased.

Now, it is evident that if one is working from a given transmitting point to a given receiving point, and if the signal energy is sent out in all directions, the energy which goes in such directions as are not that of the line connecting the transmitter and receiver, is wasted, because it continues going in its initial direction, and produces no effect at the particular receiver where one is trying to have the messages interpreted.

So that if we prevent the radiation of signal power in directions that are away from the desired line of transmission in point-to-point communication systems, and particularly if we concentrate the energy that is saved by preventing it from going in unwanted directions, so that that saved energy is also projected toward the receiver, it is possible to get a much stronger signal at the receiver, than otherwise

could be delivered with the same amount of transmitter power. In other words, the concentration of radiation in the desired horizontal direction, the direction towards the desired receiving station, results in a greater amount of power in the received signal, and consequently in a more reliable communication service, a better radio service.

This concentration of radio waves in the desired direction is analogous, of course, to the concentration of light waves, [fol. 116] by means of a reflector behind the light source, and contrasts in the analog to the circular distribution from the lighthouse.

Radio reflectors for concentration of this kind have been used. I think Mr. Hansell referred to the parabolic reflector that Marconi used at Poldhu in his transmission from there.

It is that concentration of radiated power so that it does not spread out horizontally in all directions from the transmitter that constitutes horizontal directivity in a radio system.

Now, by means of that directive concentration it is feasable to multiply the strength of the signal that is received at a given receiving point without requiring any increased power consumption at the transmitting station. That is to say, practical systems involving horizontal directivity do not merely add a percentage which would perhaps be thought of as just a small percentage to the intensity of the signal at a distance, but they actually multiply its strength so that a signal is several times as intense when received at the distant point when the energy is concentrated horizontally. That feature is of really great practical value in improving the reliability of radio service for a radio transmitter of a given power consumption or size.

And, of course, another way of saying that is that by using horizontal directivity one may attain an equally reliable service with a great saving in power, that is to say, by the use of a fraction of the amount of power that would be necessary if the energy were allowed to be broadcast in all directions.

[fol. 117] Q. 27. Now, Mr. Hogan, you have referred to the directivity diagram of the simple di-pole. Can you refer to a similar diagram showing directive radiation from an antenna? I suggest that you refer to the third Carter patent, Plaintiff's Exhibit 5, figure 3.

A. Yes, Fig. 3 of Carter patent 1,974,387 is such a diagram, showing the relative distribution or the relative concentration of the radiated power from a directive antenna system. The location of the antenna in these plots, as they are usually made in radio, is taken to coincide with the center of the diagram. That is to say, in this case, the antenna would be considered to have its center at the intersection of the horizontal line marked XX, and of the vertical line marked 90 degrees.

Now, the curved line on the plot shows the relative amount of power that is radiated in different directions from this center, and the curved line shows that amount of relative power by the distance that the curved line itself is from the center when a line is drawn to it in the direction in which we are interested.

One might consider that if one had a radiating antenna at the center where the lines intersect, and then imagined himself as projecting a line outward along the ground surface from that center of that antenna, and adjusting the length of that line so that it represented a ray in the particular direction in which it was pointed at any time, the end of the line, or the end of that group of rays would trace the path of this diagram.

Now, if a receiving station is in the direction of the XX line, either to the left or to the right, it is clear that the ray drawn from the center of the diagram to the curved line will [fol. 118] be a maximum length, and that indicates the maximum transmission of power in the direction of the line XX, either to the left or to the right. If our observing receiver is moved perhaps five degrees off of that center line up to an angle represented as half way between the XX line and the line marked 10 degrees, the radial line toward the receiver will have only a very short length to travel before it intersects the diagram of the plot of relative intensities, and that shows that as the receiver is moved about five degrees from the XX line, that the signal from an antenna having that particular radiating pattern will be very much reduced. It does not mean there will be no signal, because there is some radiation in all directions, but it does mean that the signal will be reduced by an amount represented by the ratio of the lengths of the two lines in the two directions of which I have spoken.

If our observing receiver is moved farther from the XX line, say about 12 degrees off the center line, the ray toward it will increase somewhat in length. Perhaps it is about one-tenth of that which was receivable along the line XX. That would mean that at an equivalent distance a receiver located in the line XX would receive about ten times the signal of one located in a line 12 degrees from that XX line.

Now, if the angle is further increased to about 20 degrees, the signal grows weaker. Then at 35 degrees, according to this plot, a stronger signal will be received, about one-fourth of the strength that would be receivable along the line XX.

If one went all the way around the circle on a diagram of this kind, he could thus find what the effective relative [fol. 119] power of the received signal would be at a certain distance in any direction from the transmitter, and consequently he could judge from an inspection of the plot the relative concentration of the power in any particular direction.

A diagram like this of Fig. 3 is really representative of an ideal condition, a theoretical condition, but it would be very unlikely that one would encounter such a condition in practice. That is because in any particular installation there are bound to be variations introduced to some degree by differences in the effectiveness of the radiating path in different directions, sometimes even by objects surrounding the transmitting antenna. And by surrounding, I do not mean completely enclosing, but in the neighborhood of the transmitting antenna, power lines, guy wires, other antennas, masts, all of which affect the plotting of a transmitting directive antenna in the neighborhood of the antenna.

Those effects, in many cases, are completely wiped out by distance, when one gets far away, but in taking the ordinary directive plot of a transmitter antenna, you will find usually variations that will be departures from the ideal case of this Fig. 3.

Q. 28. What type of directivity is shown in Fig. 3?

A. That is known as the bi-directive type, because the principal radiation is in two directions from the center.

Q. 29. And is there an example there of unidirective radiation from an antenna?

A. Yes, Fig. 6 on the same page of the patent, shows a pattern in which the principal direction is single or unitary,

that is to say, the principal radiation is to the right of [fol. 120] Fig. 6, and there is substantially no radiation, or at least very little radiation in the opposite direction.

Q. 30. Where is the antenna located in the case of Fig. 6?

A. The center of the antenna, as in the other case, corresponds with the intersection of the crossed lines.

Q. 31. That is to say, the horizontal and vertical line, both broken in this case?

A. That is correct.

Q. 32. Will you please continue as to directivity?

A. This type of diagram permits one to judge or to measure in principle, at least, what may be called the directivity of an antenna system. That directivity, generally speaking, defines the amount of power which the antenna radiates in a specified direction, usually the direction in which it is desired to communicate, as compared to the amount of power that would be radiated in that same direction, if, instead of the directive antenna one substituted standard comparison antenna carrying the same amount of power.

Q. 33. What is a common standard comparison antenna?

A. For horizontal V antennas, of the sort we are considering here, a proper comparison standard is the horizontal di-pole; that is usually used for measurements of that kind.

I have spoken of directivity generally in terms of the gain that the antenna under consideration would give as compared to a standard antenna.

More exactly, directivity is the ratio of the power which a particular antenna radiates in the given or desired direction to the average amount of power that it radiates in all directions. But that technical definition reduces to the other more popular figure, when one also considers the di- [fol. 121] rective pattern of the comparison antenna, so that it is proper to look at directivity as a measure either of the gain in comparison with the standard antenna or of the concentration.

To get an idea of the order of power of multiplication that is practical, I might say that a 40 kilowatt transmitter with an efficient directive antenna system is practically the equivalent, so far as its production of a received signal at a given desired point is concerned, to a transmitter of several hundred kilowatts or even one thousand kilowatt

power, if the transmitter were used with a broadcasting antenna. That is to say, power multiplications which are from six to twenty times are not at all unusual, so that instead of having the need of using a transmitter of 200 kilowatts power, it is perfectly feasible with a directive antenna to produce the same signal with say one-tenth or even one-twentieth of that power, 10 or 15 or 20 kilowatts, and consequently the cost of generating the additional 180 kilowatts of power is saved.

By that, I do not mean one can not get a still stronger signal by using 200 kilowatts of power with a directive antenna, but the equivalent signal would be to that radiated by a 2000 kilowatt transmitter and transmitters of that size have not even been built for these high frequencies.

These directive antennas give very, very real increases in the reliability of radio service, because that reliability depends upon the intensity of the received signal and the uniformity with which it is received as compared to the disturbance. The strength of the signal also contributes to the speed of signalling, because it is possible to send [fol. 122] messages more rapidly, more words per minute, with a strong signal than with a weak signal.

Q. 34. With respect to receipt of strong signals or weak signals, I would like to understand what it is you mean with respect to noise level. Will you define that word,—what it means as to the reliability of reception?

A. We grow in the habit of speaking of strong signals and of weak signals. They are comparative terms, of course. Amplifiers are available, and have been for years, so that what comes in as a weak signal can be made into a strong signal by the amplifier alone. However, that transformation of a weak signal to a strong signal does not give the useful effect that would be attained if a strong signal were produced in the first place at the receiving station. The reason for that is because what really determines the effectiveness of a received signal is how far it stands out above the residual electrical noises or static or other disturbances, which are always present in radio receivers. If, for example, one has a noise, an electrical noise level of ten units present at any particular time, and the signal has only twenty units of strength, it will be then twice as loud as the noise and will give a certain differential between the two.

If those two things are applied to an amplifier, so they are multiplied by ten, the same ratio still holds, and while the signal becomes 200 units, the noise also becomes 100 units; consequently the difference between the two does not stand out. The ratio stands fixed. On the other hand, if we think of ten units of noise and twenty units of signal, as much again for a given transmitter power, and we had a [fol. 123] multiplication of that signal strength by increasing the transmitter power, the noise has not increased as the result of that change, and the signal goes on up to many times the noise level. Consequently that gives a clean margin of useful signal which is distinguished from the noise and increases the reliability of the service and the speed of the service.

Q. 35. Please refer to the first Carter patent, Plaintiff's Exhibit 1, No. 1,623,996, and describe the disclosure there, —particularly with respect to Figs. 1 and 2.

A. The first paragraph of the specification points out that the invention relates to an improvement for transferring radio frequency energy generated at a power house to the antenna or the radiating circuit, the energy radiating circuit. By the power house here is meant the radio station. The generator is the radio frequency generator in the radio station. The antenna wires are the elements that I described in connection with the simple elementary radio transmitter as the elevated wires carrying the radio frequency currents and converting a part of, and perhaps a large part of, the energy represented by those currents into the desired radio waves.

The Carter invention solves two separate problems that had existed in the practical radio art for a good many years prior to the application date of June 25, 1933.

The first of these problems is that which has to do particularly with the part of the patent concerned with Figs. 1 and 2. This is taken up by Carter in the discussion at page 1, lines 7 to 31, where he points out that in the past it has been the custom to erect the antenna of a transmitting system as close as possible to the point where the radio frequency [fol. 124] power is generated in order to have a minimum power loss between the generator and the antenna, in the interests of efficiency and economy.

The power loss referred to in that part of the specification is the radio frequency energy generated by the high

frequency alternator or generator in the power house and applied to the system connecting it to the antenna, but which fails to get to the antenna because the connecting system is not adequately or properly designed to deliver the power without such losses.

Of course, whatever is lost on the way to the antenna is gone with respect to any ability to produce waves and again, of course, what we are trying to do in these radio transmitters is to produce all the radio waves we can, of the right kind, with a certain amount of power to begin with.

The specification continues, at line 13, to point out that circumstances occasionally arise where local geographical conditions or considerations of economy render it desirable to make use of an antenna which is located at a distance from the power house and that in the past, under such conditions, it was not possible to work efficiently, particularly with short waves, since a given length of transmission line, with such waves, represents a greater electrical distance than with long waves.

Q. 37. Have we already had in this case, Mr. Hogan, an example of lines 7 to 13, the transmitting system located as close as possible to the power house?

A. Yes; that was typical of the station arrangement up to the time of the Carter invention, and a specific case of that sort was described by Mr. Hansell in connection with the Marion, Massachusetts, long wave trans-Atlantic trans- [fol. 125] mitter, where the long antenna wires, speaking in terms of feet, were led downward directly to the transmitter house. Those wires were not long in terms of wave length, being only a fraction of a wave length in length, but they were brought directly to the transmitter house. That same consideration of length is what Carter refers to in the twenty-second line of the specification which I have just read, where he points out that when short waves are used, an antenna located a certain number of feet away from the transmitting house is a greater electrical distance for those short waves than it would be if long waves were used, the reason, of course, being that a full wave of the electrical energy is set up in the connecting system, in a distance approximately equal to one wave length, and consequently if the wave is short, there will be more of those

complete wave lengths in a line that is 600 or 1000 feet long.

Q. 38. In your experience is Mr. Carter correct in stating what the custom had been in the past with respect to the location of the antenna close to the power house?

A. Yes, absolutely. I know of dozens of stations which I personally visited prior to this time, and I don't recall a single instance in which the antenna was not brought directly to the transmitter house. That was the customary procedure.

Continuing at line 24, Carter points out that his invention has for its object the provision—I should say for its first object, he says, "for objects,"—the provision of a transmission line which will supply radio frequency energy from a power house to an antenna located at a considerable distance away, thus making possible the utilization of existing [fol. 126] apparatus at a high efficiency where hitherto only a low efficiency was possible.

There he distinguishes from what I have referred to as in my experience the usual practice in erecting radio transmitting stations so as to have the radiating antenna immediately adjacent to or as close as possible to the transmitter proper so that loss of power in transfer from the generator to the antenna might be minimized. That was recognized as fundamental procedure in the design of transmitting stations, and radio engineers knew that the large radio frequency currents in the lead-in, or the wire connecting to the antenna, were largely wasted from the point of view of causing useful radiation. It was because of that that we all made a practice of shortening that connection as far as possible by placing the antenna itself at or very near to the transmitting station.

I have indicated a situation of that sort in Exhibit 27, which shows how the generator and the tuning coils were usually placed together within the transmitting house and the lower end of the antenna connected directly to the tuning coil within the transmitter building, the ground connection almost invariably being made below the tuning coil in the transmitter house.

With respect to the conditions under which it was desirable to have an antenna further removed from the transmitter house, we might consider cases where the provision

of a good ground connection was difficult or where the ground in the neighborhood of a suitable transmitter house site was of high resistance or otherwise unsuitable for the radiation of electric waves, or where a number of antennas had to be provided and the bringing of them all together [fol. 127] at the transmitting house would be either impossible or inefficient at times because of the interaction between the closely located antennas.

Q. 40. Do you find an example of that in Plaintiff's Exhibit 23?

A. Yes; that is the map of the Sayville station and is an excellent example of a central building containing a number of transmitters and a large number of, a correspondingly large number of antenna systems in general, one for each transmitter, which it would be impossible to get to the transmitter house.

It had been attempted to meet situations of that kind by using what amount to long circuits from the transmitter house to the radiating antenna and tuning those circuits so as to produce a substantial amount of current in the circuit in spite of its length, but, of course, the act of tuning the circuit in general caused increased current in that circuit and consequently an increased loss for a given amount of power.

It had also been suggested that by transmitting a relatively feeble amount of power to a distant antenna and amplifying that power by vacuum tube or other amplifying system at the antenna, it would be possible to move the antenna away from the transmitter house.

Neither of those plans was of practical value, the long tuned circuit because of a lack of efficiency, and the distant amplifier because of its complication, and so far as I know, neither went into practical use.

Now, Carter illustrates his solution of this problem in Figs. 1 and 2 of the patent, and he describes it beginning at line 60 of page 1 of the specification. Referring to Fig. 1 [fol. 128] there is shown at 14 a generator or a source of power which corresponds to the generator that I marked 1 in Exhibit 27. This is coupled through a transformer having coils 13 and 12 to a transmission line which is marked 10 in Fig. 1 of the patent and which extends as a two-wire line over the considerable distance between the

power house and the radiating antenna which is referred to at page 1, lines 27 and 28 of the specification.

This line conveys the power from the transmitting generator to the antenna, the antenna being coupled to the line through the second transformer, having coils 11 and 2, instead of having its end connected directly to the coils 12 of the first transformer.

Q. 41. What is the type of antenna indicated diagrammatically at Fig. 1?

A. The antenna shown there is of the multiple tuned type, generally like that described by Mr. Hansell in connection with the Marion station.

Beginning at line 75 of page 1, Carter points out that in order to economize in the generating and power transmitting apparatus it is highly desirable that the apparatus should work at unity power factor, that is to say, that the current and voltage in the transmission line should be in phase.

He explains, beginning at line 84, that when the transmission is at unity power factor the losses in the line are at a minimum, that, of course, being the point for which he was striving. This minimum loss in the transmission line, which is the condition which obtains with the line operating at what is called unity power factor, he points out is a condition which may be obtained if the transmission [fol. 129] line is made reflectionless or of electrically infinite length.

That statement occurs at lines 86 to 88 of page 1 of the specification.

We have several ways of stating the same desired condition. Unity power factor is a rather technical expression, as is the corresponding expression of the voltage and current in the line being in phase. They both mean the same thing. The power factor is a trignometric function of the angle between the voltage and the current when represented in terms of time, and if the two, that is to say, the voltage and current coincide in time so that they rise and fall together, we have a condition where there is no difference of angle between the two (representing time in terms of angles), and therefore the cosine of that angle is unity, and that gives the unity power factor.

It is an engineering method of explaining the technical situation here.

The condition to attain that in a transmission line is stated in equally technical but perhaps less complex terms when it is said that the line is to be reflectionless or of electrically infinite length. The meaning of reflectionless in connection with a transmission line is not hard to visualize, because one can imagine the traveling wave of electric power, proceeding down the long line from the generator to the transformer which connects to the radiating system, and one can imagine very easily that if the energy traveling down that line is efficiently transferred to the antenna, so that it all goes into the antenna system, and is all available in the antenna [fol. 130] system for producing radiating waves, then there is no obstacle at the end of the line such as would produce the reflection of energy.

It might aid in picturing that condition to consider a rather crude sort of analog, which is apt, at least in some particulars. I have never pretended to be able to find an analog that is complete, because they do not seem to exist, but with respect to this matter of reflection one can imagine a trough or a canal, let us say, with a dike or dam or wall at the end, the canal being filled with water. If waves travel down that surface and if the energy of the wave spills over the top of the dam and is available to turn the water wheel below, the uniform progress of the energy represented by those waves is not disturbed. On the other hand, if the dike or dam or whatever we choose is made so high, that the water will not pass over it, it is quite obvious that the waves striking that will be reflected back and interfere with the passage of further waves, coming down, so that a mixture of waves traveling in the two directions will obtain in the canal.

Now, carrying the analog further, it is clear that whatever energy is represented by the returning wave is not available to do work at the load end of the canal, so to speak.

That is certainly not a complete analog, but it has helped me in fixing a picture of what may go on in systems of this kind.

The other phrase used in the patent, and to which I have already referred, namely, a line of electrically infinite length, states the picture from a little different angle. It is intended only to express the view that if waves are traveling down a line and that line is infinite in extent, they won't [fol. 131] come back, they do not reach at the distant end

any reflecting point which will turn them back, because the distant end is at infinite distance.

That term is used in electrical engineering to express a condition of absence of reflection which is the way it is used here, but, of course, in connection with a system where power is to be transferred from the generator to a radiating antenna, the line from the generator to the antenna is not equivalent to an infinitely long line with respect to the transmission of power, because no power would ever get through a line, if it was actually infinitely long. It is only a way of expressing the absence of reflection, which has also been stated in those same words, namely, "made reflectionless".

Carter continues, at line 89, to point out that under these conditions where the line is reflectionless or of electrically infinite length, no waves can be reflected back from the ends to interfere with the natural flow of energy into and out of the transmission line.

That is a summary of the more complete explanation that I have just endeavored to give.

Now in a transmitting system of the sort shown in figure 1, this two-wire line extending from the power house where 12, 13 and 14 are located, over to the antenna where the transformer 11 and 2 is located, may be physically relatively long, that is, its ends, where the transformer coils 12 and 11 are connected, would be separated, what Carter terms a considerable distance, such, for example, as would be electrically substantial and equal to several wave lengths.

If we were considering a 50-meter wave length, for example, that corresponds to about 165 feet, the trans- [fol. 132] mission line, ordinarily would be several hundred feet in length.

Now, Carter recognized that the loss of the power in such a transmission line was proportional to the square of the current in the line, and to the resistance of the line. He states that, beginning at line 80 of the specification, where he points out that "the power loss, including radiation in any transmission line is I^2R, where I represents current and R the effective A.C. resistance, including the radiation resistance."

There he is talking, not about the antenna, but about a transmission line, and he is stating, in engineering terms, that in order to reduce the losses on the line, the factors which define loss should be kept at a minimum value. He

does not say that in those words, but that is the normal engineering meaning of the definition of what constitutes the losses.

Now, in examining that, we see that since the power is fixed by the square of the current times the resistance, the total resistance, we want to have a condition in which the current in the line is not unnecessarily large, obviously we want to keep that current down to the smallest value which can transmit the power that we require to pass through the line at the voltage which will appear in the line, and that occurs at this condition of the unity power factor, to which I have referred, because under a condition of unity power factor, the voltage and current are going along hand in hand at all times, they are doing their utmost with respect to each other, and since the product of voltage and current represents the co-operation between the two and is the thing that [fol. 133] defines power, we there have a condition of maximum power with a given voltage and current in the transmission line.

Now, looking at the other factor which defines the power, namely, the total resistance R, which, as Carter states is the effective alternating current resistance, including radiation resistance, we see two things: First, that the mere conductor resistance should be minimized. That, of course, has always been well known, that if the losses in transmitting electricity through wire are to be minimized, the resistance of the wire should be minimized, but there is a second feature, namely, that that R includes radiation resistance of the transmission line.

That brings in the concept which I have not discussed, namely, that even a two-wire line, of the sort shown in the Carter patent, does radiate a small amount of power. Now, of course, our desire in such a transmitting station is to have the power radiated by the antenna and not by the transmission line. Consequently, an indication that R includes radiation resistance of the line is a teaching that that should be kept small in order to reduce again the losses in the transmission line itself.

Q. 42. At one place in your answer, Mr. Hogan, you say that for a wave length of 50 meters, the transmission line would be at least several hundred feet in length. I assume you did not mean that the length of the line would be determined by the wave length.

A. No, I simply meant that in a practical case a line several hundred feet in length; while that, thought of in feet, is not a great distance, it does amount to several wave [fol. 134] lengths at a practical wave, such as 50 meters; under these circumstances, that would be a considerable distance, as Carter expresses it. In other words, we must think of the distance in wave lengths, rather than the distance in feet when we think of the electrical distance or when we attempt to say what a considerable distance between a power house and an antenna is with respect to the use of Carter's transmission line.

Q. 44. Before you take up the method by which Carter secures this reflectionless line, is this reflectionless line equally applicable to other types of antennas than the ones shown in Figs. 1 and 2, for example?

A. Yes. Figures 1 and 2 both show the multiple tuned antenna. Fig. 3, for example, shows the simple old vertical type of antenna, and any other type of antenna or radiating system might be used such as the horizontal or vertical di-pole, to which I have referred, or the V antennas which we are concerned with here. In fact, any type of radiating system.

Q. 45. Will you explain how Carter secures his reflectionless line?

A. Yes, I have pointed out that the desired result of minimum current in the line and consequently a minimum loss along the transmission line could be had by preventing reflection of the energy from the remote end of the line, that is, the load end of the line, the end away from the generator. That prevention of reflection avoids the development in the transmission line of currents that represent the reflected energy.

Beginning at line 92 of page 1 of the specification, Carter points out:

"This result may be obtained by closing the transmission [fol. 135] line 10 at 11 in such a manner that the effective impedance at the load end of the line is equal to the surge impedance of the transmission line."

In that connection, I should first point that "closed" in the electrical sense is diametrically opposite to closed in the single physical sense, such as closing a door and preventing

the passage of anything through that door. When Carter says a line is closed in a certain way, he means that the ends of the line are connected together as by the coil 11 or in some other way a termination is made which electrically closes the line, but does not prevent the flow of electricity to the antenna system.

Now, the requirements that the effective impedance at the load end of the line shall be equal to the surge impedance of the transmission line is equivalent to saying that the condition, the electrical conditions at the end of the line away from the generator shall be such that there is no electrical discontinuity of the sort that would set up reflection, that that is nothing at the far end of the line which will prevent the energy from being effectively transferred from the end of the line into the antenna system.

Carter explains in the next paragraph what is meant by the surge impedance of the line. It is represented by the symbol Z_0, and is stated to be approximately equal to the square root of the inductance divided by the capacity. That surge impedance is thus a characteristic of the line construction, it is independent of the frequency of the currents carried by the line, and it is also independent of the values [fol. 136] or the adjustments of any electrical apparatus which may be connected to either end of the line.

The other factor referred to at line 95 is the effective impedance at the load end of the line. Now, that is the effective terminal impedance of the antenna because the antenna is what provides the load, and Carter's teaching is that the effective terminal impedance of the antenna shall be made to equal the surge or characteristic impedance of the transmission line.

Your Honor will perhaps recall that the impedance of any electrical circuit is its effective angular or geometric resistance for alternating currents. That is to say, it is a carry-all term, which adds up geometrically, the current-opposing effects of simple resistance, as it is observed in direct current circuits, and of capacity and of inductance. Those three factors all come into a determination of the value of the terminal impedance of a circuit.

Further than that, the frequency of the alternating current, applied to the circuit, comes into the measure of the impedance because of the fact that while the resistance part of the impedance does not change appreciably or practically with the frequency, the reactive effects of both inductance

and capacity in the circuit do change with the frequency of the current.

For example, given a certain amount of inductance, and that is to say, a certain size of practical coil, the higher the frequency of the current going through there, the more strongly the magnetic field produced by that current reacts, and consequently we say the greater the inductive reactance [fol. 137] of that particular coil will be. The higher the frequency of current, the greater the inductive reactance.

That is one of the three elements of impedance. With respect to a condenser the opposite of this occurs, the higher the frequency of current applied to it, the more current goes through the condenser, consequently we say the lower the capacity reactance of that condenser is, the capacity reactance decreasing as the frequency goes up.

Now, the combination of those three things, really those four things, inductance, capacity, resistance, all make up impedance, and the frequency value which determines the effect on impedance of inductance and capacity—all of those go in to determine the effective reactance and the effective impedance of such a circuit as the antenna circuit that we are speaking of.

Q. 46. May I try to summarize that in brief form, and tell me whether I am approximately correct: With respect to direct current the current is impeded or prevented from flowing to an unlimited extent by the resistance in that circuit. With respect to alternating current the same resistance tends to decrease the amount of current flowing for any given voltage or pressure, but in addition there are two other elements which tend to impede the flow of current through the circuit and those are first the reactance set up by the condenser or some other capacity, and second the reactance set up by an inductive coil or some other inductance; and that the sum of those three, the capacity reactance, the inductive reactance, and the resistance, is the impedance of the circuit to the alternating current flow?

A. That is absolutely correct except that one cannot take [fol. 138] the simple arithmetic sum of the three values, but has to consider them geometrically; but the general statement is entirely correct.

Q. 47. Now will you take up the surge impedance, please, Mr. Hogan?

A. Yes. This surge or characteristic impedance, of a transmission line. I think it can be seen from what I have said, is an entirely different thing from the effective terminal impedance of a load or circuit. In practical radio frequency transmission lines of the sort we are concerned with here, the surge or characteristic impedance depends only upon the amount of inductance and the amount of capacity of the line itself. Those values, that is, the inductance and capacity values, are usually measured for a unit length of the line. For example, per foot or per meter of the line. They are determined in these lines by the size and spacing of the two wires that make up the line. In other words, the surge impedance is also called the characteristic impedance of the line, and it is a physical electrical characteristic of that line itself, regardless of the length, regardless of what is in the line, regardless of what is connected to the line, and dependent only upon the inductance and capacity per unit length, as given in the equation at line 105 of the Carter specification. Inductance and capacity per unit length are in turn determined by the size of the wire—in these practical lines—by the size of the wire and the distance between the two wires. To take a practical value, in the transmission lines with which we are here concerned, the construction is a pair of No. 6 copper wires spaced 12 inches apart. No. 6 wire is quite heavy, nearly [fol. 139] one-quarter of an inch in diameter, and such a pair of wires, with the 12-inch spacing, produces, as I have said, regardless of the length of the line, a transmission line which has a characteristic impedance or a surge impedance of approximately 600 ohms; that is the figure which will recur during the description of the defendant's apparatus.

Q. 48. You have said that the surge impedance is different from the effective terminal impedance of a load or circuit. Is it also different from the terminal impedance of the generator?

A. Yes. The terminal impedance of a circuit—any circuit—even if it is a circuit that is so greatly elongated as to constitute a transmision line, depends on these other factors such as frequency of the currents carried in the circuit, on the total or series resistance of the entire circuit, on the total effective inductance and capacity of the circuit, and including the resistance and inductance and capacity of the apparatus connected at the ends of such elongated circuit, or constituting a closed circuit.

In general we have terminal impedance for any kind of an electric circuit, depending upon these various factors. It can be measured between two points in any kind of a circuit. On the other hand, surge or characteristic impedance is only applicable to what is called a circuit having a distributed constants, or smooth constants, not a single lumped inductance or capacity, but to a circuit such as is represented by a transmission line. Broadly speaking, this condition, defined by Carter at lines 93 to 97, namely, the adjustment of the resistance at the remote end of an electric transmission line, so that it equals the surge or characteristic [fol. 140] impedance of the transmission line itself, is called matching the terminal resistance, the end resistance, the load resistance, to the surge impedance of the line.

Now with respect to Fig. 1 of the Carter patent, coils 11 and 2 constitute a transformer, and by just adjusting the number of turns in each coil and the coupling between them it is possible to control the voltage ratio or transformation ratio of that transformer, and in that way the effective resistance of the tuned antenna system, as it appears at the primary coils may be controlled so as to equal in value the characteristic impedance of the long transmission line 10.

Fig. 2 of the Carter patent is very similar, except that the two-coil transformer 11 and 2 is replaced by an auto transformer or one-coil transformer marked 22 in Fig. 2 of the patent. Carter, at page 2, beginning at the fourth line, points out that in Fig. 2 the transmission line is closed through a suitable amount of coil 22, such that the effective impedance of this part of coil 22, with its antenna load, is equal to the surge impedance of the line, that is to say, the apparent impedance of coil 22 with the effect of the antenna load or resistance upon it, is changed by changing the amount of the coil which is connected with the line 10 so that at the terminals of the transmission line, where it is connected to the coil, there appears a resistance equal to the surge impedance of the transmission line.

By those adjustments he attains the desired reflectionless or so-called electrically infinitely long line in which the high frequency alternating current is represented by traveling [fol. 141] waves that flow along the line from the transmitter to the load end remote from the transmitter.

Those traveling waves represent a flow of energy from the transmitting generator to the radiating antenna, and the purpose of Carter's match is to get the maximum energy

from the input of the transmission line into the antenna for use in the antenna to produce electromagnetic waves. And to attain that result he sets up this reflectionless condition of matched terminal impedance to surge impedance such that there is no reflection, and no energy is wasted or prevented from going into the load, that represents the condition of high efficiency in the transmission line itself.

Traveling waves to which I have referred are waves which carry energy in one direction. They can be represented in a simple analog by the sort of wave which travels along a rope when the far end of the rope is left loose, is not tied to anything. One puts a kink in the rope, and the wave travels down to the end, and the waves are not reflected back because there is nothing to reflect them at the far end of the rope. Similarly, if one has a long kite-string, and sets up a wave motion on the string, if the kite is far enough away so that the waves are not transmitted that far, then there is no reflection, and you have an example of traveling waves.

Electrically these traveling waves in a transmission line are characterized by the fact that at the instant when the voltage at one point of the line is a maximum the current in the line at that point is also a maximum. Similarly, when the current at a given point is—when the voltage at a given [fol. 142] point is a minimum, the current at that point is also a minimum.

Further, in a line carrying traveling waves, the average value of the voltage or of the current all the way along that line is uniform. Now, such a condition exists in this line used by Carter for the transfer, the efficient transfer of power from his generator to his antenna. In contrast, if there is reflection from the remote end of the line, that is equivalent to setting up a reversed or reflected wave traveling in the opposite direction, and the reflected energy combines with the energy flowing from the transmitter so as to produce standing waves in the transmission line. Those standing waves cause the amount of average current or voltage measured at various points along the line to be different. If energy is not transferred efficiently from the remote end of the line to the load, reflection will be produced in that way and line efficiency will be reduced. If all the energy reaching the end of the line is efficiently transferred to the antenna or to the load so that it can be used to do work there, which is what we mean by speaking of the antenna

as a load, then there is no reflection, the line efficiency is high and the energy that is transferred is delivered to the antenna for producing radiation. Of course, where there is reflected energy it goes back into the line and does not get into the antenna, and consequently it is lost in so far as its availability for producing radiation is concerned.

Now, I have pointed out that reflection of energy causes a combination with the energy going from the generator toward the antenna and thus standing waves are produced, that is to say, a condition where the voltage and current in [fol. 143] the line is larger than when there is no reflection, the excess current and voltage that is represented by these differences in value, that excess (that is caused by the presence of the undesired standing waves produced by the reflection in the line) is a measure of and represents the energy that is wastefully present in the transmission line, in other words, a measure of the lack of efficiency.

The standing waves in the line represented by the combination of the two waves, one, the main wave traveling toward the end of the antenna and two, the reflected wave, are called standing waves because they have stationary positions in space where current is either a maximum or a minimum, just as when a cord is tied to a post and waves are set up in that, the waves will be reflected back, and by timing correctly one can get a condition where waves appear to move in neither direction but simply where the line changes from side to side and there is no indication of a progress of a wave down the line.

Summarizing, it can be said that Carter's result of high line efficiency for the transfer of power effectively into an antenna so that it may be radiated from that antenna, can be attained by operating the line at unity power factor or by maintaining the current and the voltage along the transmission line in phase, that is to say, with the maxima of both voltage and current occurring at any one point at the same instant. I think I have explained that is equivalent to unit power factor.

The third way of stating it is that it is attained by making the transmission line equivalent to one of electrically infinite length in the sense that no reflection occurs and that, of course, brings in the fourth statement that it is attained by [fol. 144] making the line reflectionless, and finally, that con-

dition, defined in any one of those ways is had by closing the transmission line, terminating the transmission line, so that the effective load resistance is made equal to the surge impedance, the characteristic impedance, of the transmission line.

Carter's discovery that he could connect a high frequency generator by means of a long high frequency transmission line of high efficiency, because of its adjustment of that character, the connection being to a remote antenna, provided a practical solution for that problem of separating the antenna and the transmitter house.

I have pointed out, I think, at page 1, lines 19 to 20, that this had been particularly difficult with short waves, and of course this solution of Carter's has turned out to be a practical success and it has been in continuous and extensive use for a number of years.

Q. 49. The Carter patent at page 1, commencing line 31, states that "Another object of the invention is to provide a new and improved system giving directional transmission, utilizing separate antennæ fed from a single source through a plurality of transmission lines." Will you please explain how this object is attained, referring to Figs. 3, 4 and 5?

A. Recognizing that the transmission line is an electrical connection from the source to the radiating portion and that its primary function, or, rather, that the primary function of the entire transmitting system is to convert as much as possible of the generated power into radiated waves, and, consequently, recognizing that the power must be conveyed from the generator to the antenna, the desirability of getting as much of that power to the antenna as is possible, is clear. [fol. 145] That applies not only to the arrangement of Figs. 1 and 2, where only a single antenna is involved, but also to the use of several antennas whose effects are to be combined in order to produce directive radiation.

At the time of Carter's application for patent No. 1,623,-996, it was known that two antennas spaced a quarter of a wave length apart and electrically excited with equalized high frequency currents that differed in their timing or their phasing by one-quarter of a cycle would be expected to radiate more in a desired direction than in the others, and little if at all in the direction opposite to the desired direction. Carter shows in Figs. 3 and 4 of the patent such pairs of antennas spaced a quarter of a wave length apart, the fraction lambda over 4 at the bottom of Fig. 3 and at the

upper part of Fig. 4 representing the quarter wave length distance between the antennas.

The Greek letter lambda is the symbol customarily used to represent wave length and of course that, divided by 4, represents one-quarter wave length.

Fig. 5 in the patent shows a directive characteristic of the radiation of such a pair of antennas when they are equally excited in the right relative phase or with the right relative timing, that is to say, when the maximum current in each of the two antennas occurs at times that are separated by one-quarter of a period or one-quarter of the time of one cycle.

However, in applying his invention to the multiple antenna systems of Figs. 3 and 4, Carter did not merely arrange to deliver power to those antennas efficiently, but he solved other important problems in connection with the [fol. 146] combination of antenna elements for the production of directive radiation.

The arrangements of Figs. 1 and 2 that I have already described are not in themselves sufficient to take care of these other problems that arise when one has two or several radiating units of a directive antenna system and when one has to supply power to them as in Figs. 3 and 4.

I have referred, for example, to the loss of power by random or undesired radiation from a transmission line; that is a mere power waste in connection with the systems of Figs. 1 and 2, but in connection with directive systems, such as those of Figs. 3 and 4, it is not merely a power loss but it has an adverse effect upon the directive pattern, upon the distribution of energy. Where one is endeavoring to concentrate power in one direction it is all the more important to avoid waste in unwanted radiating directions.

Thus it is more important in such directive systems, that substantially all of the power radiation should take place from the antennas themselves and as little as possible from the transmission line connection between the transmitter and the antennas. The two wire lines that Carter shows with their wires relatively close together and consequently having—as I pointed out—small radiation resistance in order to meet the condition of minimum loss that he set forth at page 1, beginning at line 80, give a connecting system which even though it may be long, has little, if any, interfering radiation, and which conveys the bulk of the energy effectively from the generator to the antenna so that it may

be radiated from the directive antenna combination itself. [fol. 147] Because a reflectionless line conveys a certain amount of power with the lowest value of line current and voltage for the delivery or conveyance of that power, such small radiation as would exist in the case of the two wire line is therefore minimized by the matching that Carter teaches, because that matching reduces the value of current and voltage for a given amount of power.

Now, although the arrangement of Figs. 1 and 2 is adequate for conveying power efficiently to any kind of antenna system, it does not show how to maintain the correct phase displacement between the two antenna systems, which are driven from a source.

In directive systems like those of Figs. 3 and 4, it is important to fix a relative phase or time difference of the current in each of the two antennas and also to fix the relative amplitudes of those currents and it is also important to fix those in a stable way which will not be subject to erratic variations.

To do both those things, both being of importance, Carter matches both of his antennas to the surge impedance of the power line. Of course, the line from one antenna section to the other antenna section, may be only one-quarter of a wave length long, and therefore physically short and even electrically short, a fraction of a wave length, and because of that, the mere gain in efficiency that is produced in that section of the line may be of relatively small importance and one might think that the primary reason for using the match secured in connection with Figs. 1 and 2 would not apply to a directive system where the antennas are spaced by such a relatively short distance. However, because in a [fol. 148] matched line, such as is shown in Figs. 3 and 4, the voltage and current at any point of the line rise and fall together, and because the maximum of current and voltage at different points along the transmission, separated by any particular distance, any particular fractional wave length, always occurs with a phase difference that is proportional to that distance, when the line is carrying traveling waves only, there is provided in this matched line a simple and effective and stable way of determining the relative phase and amplitude of the currents in the two separate antennas.

When Carter further, in Figs. 3 and 4, drives the two similar antennas through matched transmission lines at points that are separated by a quarter of a wave length along this matched transmission line system, he arranges matters so that automatically the two antennas have generated in them enough currents that are of equal amplitude and which differ in phase by that same amount, a quarter of a wave length, which corresponds to 90 degrees or a quarter of a period, and that represents the desired condition for multiple antennas, such as are shown in Figs. 3 and 4.

With the Carter arrangement that desired difference in phase is fixed very simply and definitely by the mere difference in length of the matched transmission lines that supply the power to the two antennas and the desired equality of the current in each of the two antennas is also fixed by the matching.

Because of those two facts the condition that is needed is easily attained and also it remains stable and is independent of critical adjustments.

[fol. 149] Carter describes this as to Fig. 3, beginning at page 2, line 10, pointing out that the antennas are located one-quarter of a wave length apart, they are energized through transmission lines 10 and 10′, and that the same adjustment of the coupling coils 38 and 38′ is made as before.

By that he means the adjustment which matches the load impedance or resistance to the surge impedance of the line, so that those lines are matched or become of electrically infinite length with respect to their absence of reflection.

Similarly as to Fig. 4, which he describes beginning at page 2, line 22, he points out that the arrangement is substantially equivalent to that of Fig. 3, he describes the coupling between the transmission line and the antenna, and its adjustment to give an effective impedance equal to the surge impedance of the line. He also refers to the directional characteristic of Fig. 5, at lines 38 and 39.

With respect to the control of the phase in the antenna systems, which I have described, he says, beginning at line 40, page 2:

"It is to be noted that my transmission line lends itself particularly to directional systems comprising a plurality

of antennae, since the proper phase relation of currents in the various antennae can readily be obtained with a maximum efficiency of transmission line."

Q. 50. In connection with Fig. 4, might occasion arise when both antennas 41 and 41′ are to be located at a considerable distance from the power house?

A. Yes, indeed; the distance between the antennas is [fol. 150] only a quarter of a wave length, and it would often be desirable, and perhaps most of the time as in the case of a single antenna, to locate both of them at a distance from the power house.

Q. 51. And in this case, applying the teachings of Carter with respect to his first object, would there be any matching of the load resistance to the surge impedance at point 13 or in the neighborhood of that point?

A. Yes, what one would do would be to match the surge impedance of the long line coming from the transformer house, and connected to transformer coil 13 in either Fig. 3 or Fig. 4, by adjusting the transformer of which 13 is the primary, so that the effective load at the terminals of the transmission line where it is connected to 13, would equal the surge impedance of the transmission line. In that way, the teachings of the patent with respect to the long line and separation of the transmitter and antennas would give the highest efficient transmission line.

Q. 52. Now, would you summarize the advantages as you see them of the disclosures of this first Carter patent, I mean the practical advantages?

A. Yes, I think they could be tabulated by saying first, the antenna, or antenna sections may be located at a considerable distance from the generator as Carter pointed out in the first part of the specification.

Second, in spite of that distance of separation, power could be transferred to the antenna system with a minimum waste.

Third, a number of antennae units could be combined to cause directive radiation without harmful effects of spurious [fol. 151] or undesired radiations from the connections through which the power was transferred to the antenna.

Fourth, by using a single generator to supply both or all of the antenna sections, there would be provided a fixed

phase reference, so that the relative phases of each of the antenna sections would be maintained with respect to a single source.

Fifth, the relative phases of the currents in each of the antenna sections could be determined merely by selecting the desired length of traveling wave or reflectionless transmission line.

Sixth, those relative phases could be maintained without the need of frequent adjustment or critical adjustment at any time.

And seventh, the currents in the several antenna structures could be equalized, or could be controlled and maintained in the relative values desired.

Those, I think, are the principal practical advantages.

There is another feature which flows from the use of these lines, which is of considerable practical importance, and that is that when it is intended to use a system of this kind involving a matched transmission line, a reflectionless transmission line, the transmitting unit, the radio frequency generator unit (and, of course, today they are usually of the vacuum tube type), can be designed so that it is intended for connection to a load of a standard value, as, for example, the 600 ohms, of which I spoke. That means that one can build such transmitters, designing them for a particular value of that sort, and then can use them any- [fol. 152] where with any kind of an antenna system, no matter how complex the arrangement of the antenna is, nor at what frequency it is operated. And by using the 600 ohm line to connect the transmitter to the antenna, the transmitter is worked under the conditions for which it is designed.

If one didn't have such a set-up, it would be necessary to consider the antenna design in designing the transmitter itself.

Q. 53. Now, will you please turn to the second Carter patent in suit, Plaintiff's Exhibit 2, Patent No. 1,909,610, and explain the general nature of its disclosure?

A. The application for this patent No. 1,909,610 was filed March 12, 1930, nearly seven years after the application for the earlier Carter patent, which I have just considered.

The second Carter patent describes a specific and an improved way of adjusting high frequency transmission lines so as to get the desired high frequency explained in the earlier specification; that is to say, this shows a specific way of providing the reflectionless match between the resistance of the load or antenna and the surge or characteristic impedance of the transmission line. That reflectionless match resulting in a transmission line of electrically infinite length in the way I have described.

Where the load is provided by an antenna system, in the case of this second Carter patent, just as in the case of the first Carter patent, the antenna itself may be of any type, such as the vertical wires that I have described, and that were illustrated in the other patent, or the multiple tuned [fol. 153] antenna, or the horizontal wires or di-poles or the V forms of antenna.

Beginning at line 4 of page 1, Carter says, that

"In order that the line transmit energy at best efficiency; that is to say, without reflection, it is desirable that the line be terminated by a load which equals in impedance the surge impedance of the line."

Q. 54. And as I understand it, that was the teaching of the first Carter patent, is that correct?

A. That is correct. This is a little more general statement, but the substance is the same.

He explains as his object in greater detail, beginning at line 14, and says:

"it is an object of my invention to provide a method and means for terminating a line to which a load is connected so that the termination means combined with the load presents the correct impedance to the line."

That again is, while more specific, a rather general statement, since it refers to the correct impedance which we have already discussed.

Then beginning at line 19, he says, more specifically:

"I accomplish this by connecting a variable reactance across the line at a distance away from the load such that the circuit formed thereby including the variable reactance, the line portion between it and the load, and the load, presents an impedance equivalent to the surge impedance of the line."

[fol. 154] That describes in more specific terms his new circuit for attaining the reflectionless or high efficient condition.

The variable reactance which is referred to at lines 23-24 is a capacity or an inductance. He connects that at a point or across a pair of points along the transmission line between the source of power at one end and the load which is at or near the other end of the line.

He selects the distance between the load and this point where the reactance is connected, so that the combined effect of that shunt reactance (that is to say, that inductance or condenser), of the resistance of the load and of the section of the transmission line between them, provides at the point where the reactance is connected, a value of impedance or of resistance that equals the surge impedance of the line.

Now, the specification describes several variations of this new matching circuit. Fig. 2 shows the source which is a generator marked 2, connected through the transmission line marked 6, to the load represented by resistance 4, at the right of Fig. 2.

The figure is explained briefly at page 1, beginning at line 81—and in greater detail on page 2, beginning at line 18.

Carter points out that in this arrangement of Fig. 2, the load resistance 4 is less than the surge impedance, and the distance between the point at which the variable reactance 10 is connected and the point of the load (namely, the end of the line) is to be not more than one-quarter of a wave length along the line.

He explains, at page 2, line 40 and following, that the same result may be had by connecting this reactance in the [fol. 155] third, fifth, and so on quarter wave sections. As when the connection between the load and the reactance is beyond the first quarter wave length point, or in the first quarter wave section.

Fig. 3 is described briefly at page 1, line 86 as being an arrangement for properly terminating a line wherein the load resistance is greater than the surge impedance of the line.

That is an opposite condition with respect to the relation of load resistance and surge impedance from that shown in Fig. 2. To provide the desired match under the second condition, the inductive reactance marked 12 in Fig. 3, is connected across the transmission line 6 at a point that is less than one-quarter of a wave length from the terminals

of the resistance load 4. Similarly, beginning at page 2, line 60, Carter explains that the connection may be made in a later or more remote quarter wave section of the line rather than the first, that is to say, in the third or fifth and so forth.

Beginning at line 28, at page 1, the specification gives the necessary information as to the use of either a capacitative reactance—that is to say, a condenser,—or an inductive reactance—that is to say a coil—depending upon whether the load resistance is greater or smaller than the surge impedance of the line, and also depending on how far from the load one may desire to connect the reactance across the line.

On page 2 of the specification, beginning at line 69, Carter refers to Fig. 4, and says:

"I have shown the actual values of the elements involved where a line having a surge impedance of 600 ohms [fol. 156] supplies a load of 300 ohms."

Then he goes on to point out, as is shown in that figure, that in that event, the capacity reactance of 840 ohms should be connected across the line at a point which is slightly less than one-tenth of a wave length from the load to the point or connection where the line is matched.

At the end of the specification, page 2, line 90 and following, Carter gives a tabulation which shows four different cases, the relations between the ratio of load resistance and surge impedance, the line section length, and the character of reactance to Z connected across the line.

In this tabulation in the right-hand column of page 2, the line section lengths are stated as less than one-quarter wave length and as greater than one quarter but less than one-half wave length.

Those two phrases define respectively connection in the first or the second quarter wave length sections of the transmission line as one measures distance from the resistive load toward the source.

Beginning at line 41, and again, at 63, on page 2, Carter points out that connection in either of these first two sections, that is, the first quarter wave section or the second quarter wave section is preferable.

He also shows, though, at page 1, beginning at line 60, that similar results can be obtained when multiples of these

quarter wave section distances are chosen, and goes on to explain what he means by multiples of the distance.

Beginning at line 18, on page 2, he points out that in the case where the surge impedance is greater than the load impedance or load resistance, he may either connect [fol. 157] a capacity across the line in the first quarter wave length section, or an inductance across the line in the second quarter wave length section, or again, the capacity across the line in the third wave length section, and so on.

That description ends at page 2, line 40.

Then, beginning at line 44, on page 2, he points out that in the event that the surge impedance is less than the load resistance proper termination is had by connecting an inductance in the first quarter wave length section or a capacity in the second, or the inductance again in the third, and so forth.

That description carries on to line 63.

Immediately after he points out again that he prefers to connect the reactance as closely as possible to the load, so as to include a minimum section of the line between the reactance and the load. That, of course, gives the greatest length of matched line, high efficiency of line.

This new type of matching circuit in any one of the four cases to which I have referred, represented by the four lines in the tabulation at page 2, line 90, permits one to get the transmission line of unity power factor or electrically infinite length, which is generally described in the earlier patent, No. 1,623,996, but without having to use the type of matching transformer that was shown in that patent.

Those transformers are difficult and expensive to construct in such a way that they will give maximum coupling and also sufficient insulation for the high voltages that are common in the transmitting antenna systems; and also they are relatively difficult to adjust.

[fol. 158] The new idea set forth in this second Carter patent, of replacing the matching transformer by a part of the transmission line itself plus a simple capacity or inductance connected across that line at a proper distance back from the load, avoid those transformer difficulties, and it gives us in practice a very satisfactory structure.

In setting up a system using the matching arrangement of this second Carter patent, the transmission line is run directly from the source or the generator to the load or the antenna, and it is not necessary to disturb that line or to

modify it in any way in order to make the adjustments that one has to make so as to match the load resistance to the surge impedance of the line.

That simple procedure of connecting a reactance, either capacitive or inductive in any one of the quarter wave length sections that one may desire to choose, whichever is the most convenient, in accordance with the teaching of the Carter tabulation here, is in definite contrast to some of the earlier matching schemes, such as the transformers or the quarter wave length copper tubes with adjustable spacing that are used in some of the defendant's antenna systems.

For example, the copper tube type of adjustment requires that the tubes should be located so that the ends nearest to the antenna are at a point where maximum or minimum current would occur in the antenna wires before the tubes were adjusted, and it is hard to locate points of that kind before the system is completely connected.

If one inserts these tubes at the wrong point, then in order to move them either toward or away from the antenna, the wire must be cut and repaired correspondingly; [fol. 159] and the same sort of thing is necessary in connection with the transformer operation, although there you are not limited to the points of connection fixed by current maxima or minima.

Your Honor will doubtless appreciate that there is a real practical advantage in a structure where, after an antenna is built, one needs only to run an ordinary transmission line all the way from the generator to the antenna, and without having to consider while doing that what type of matching device you are going to use, or where you are going to locate it, or whether you have to build a house in which to put it, or any of those factors.

With Carter's matching system of this second patent, after the transmission line was put permanently into place, he made the desired adjustments simply by connecting across it at a convenient point, either a coil or a condenser, or a capacity or inductance, provided in some other way, and in that way the line from the transmitter to the far end of the antenna was, in effect, an unbroken and uniform conductor, extending all the way from the generator to the far distant end, and it did not have to be modified by the insertion of any apparatus for the attainment of the desired match.

I can summarize the disclosure of the second patent by saying that it is a practical circuit for matching the surge impedance of a transmission line, and the resistance of a load such as an antenna, and that it has advantages which can be tabulated as
[fol. 160] First, that no transformer, or other elements that are difficult to design for maximum effectiveness are required.

Second, that the circuits may be arranged so as not to use any element requiring protection from outdoor weather.

Third, that the transmission line may be initially run directly from the source to the load whatever the positions of either of those may be, and the matching adjustment then made without altering the line in any way.

Fourth, the adjustments that are made for the matching are comparatively quick and easy to find.

Fifth, once adjusted, the system maintains its characteristics stably and requires no attention.

And, of course, finally, the matching system is extremely simple and economical.

Q. 55. You stated that one of the advantages of the circuit arrangements of the second Carter patent was that the circuits might be arranged so as not to use any element requiring protection from outdoor weather. I show you Plaintiff's Exhibit 14 and ask you whether in the arrangement shown in that circuit there is any protection from the weather of the matching circuit?

A. Yes, the matching circuits are enclosed within the boxes that are indicated by the rectangular enclosures in Exhibit 14.

Q. 56. Will you now please refer to the first Lindenblad patent No. 1,884,006, and explain the disclosure of that patent with respect particularly to Figs. 1 and 2?

A. This patent discloses the structure of an improved directive antenna using a pair of long wires. It is prin-
[fol. 161] cipally concerned with the radiating antenna itself and does not relate specifically to the transmission lines.

The application was filed September 7, 1928, more than five years after the application date of the first Carter patent which I have discussed, and after a good deal of

work had been done in the development of short wave communication, but at a date earlier than the application for the second Carter patent, No. 1,909,610.

At the opening of the specification, Lindenblad points out that the invention relates to antennæ, and more particularly to directional antennæ for the propagation of reception of short wave signals.

In the second paragraph of this specification, he goes on to say that various forms of beam or projector antennas developed at prior dates are complicated, expensive to erect and to adjust, and that those prior art complicated antennas are structurally suitable only for use with the particular wave length for which each one was designed and built.

At lines 11 to 19, he points out that his new antenna is composed of simple linear conductors, and that it is in such form that a single antenna structure is suitable for use with any one of a considerable number of wave lengths.

In the third paragraph of the specification, beginning at line 25, Lindenblad describes the radiation from a single long linear or straight conductor, and by that he means a wire which is several wave lengths in length. He refers to the case when the wire is carrying standing waves.

Later in the specification, page 4, lines 120 to 122, he gives an example of such a long wire as one approximately eight [fol. 162] mean waves in length, that is to say, approximately eight wave lengths long.

I think that I have pointed out that a long wire is long when it is several wave lengths in length. That is, that the unit we must consider in connection with the description of long wires or long lines is the wave length and therefore that a single wire of a certain physical length in feet may either be long or short, depending upon the wave length at which it is used. For example, a 600 foot wire would be long for a wave length of 50 meters, because 50 meters is only about 150 or 160 feet, and there would be nearly four wave lengths on the wire. On the other hand, that same wire, if it were used at a wave length of 600 meters would be a short wire, because in that case, it would be only about one-third of a wave length long.

The Court: In other words, it is all relative?

The Witness: Yes, it is all relative, and unless we know the unit, we can not judge the length of the wire, knowing

the length of the wave length, we can tell, whether it is a fraction of a wave length long, and therefore a short wire, or several wave lengths long, and therefore a long wire, in the sense that we are using those words here.

When the energy of alternating currents is fed at one end of a wire, and is practically entirely abstracted or usefully used at the other end, or if the energy is used up along the length of the conductor, then there is no effective electrical discontinuity at the far end, and consequently there [fol. 163] is no reflection of energy from that far end back along the wire.

Under conditions of that sort, we say that the wire carries a traveling wave only and considers that the alternating current energy travels from the point where it was supplied toward the point where it is used up.

On the other hand, if there is a discontinuity—an electrical discontinuity—or an abrupt change in the electrical values at the remote end of the line, of the sort we have been considering, the energy that reaches that end of the line as a traveling wave is reflected and the reflected or returning energy or wave of energy, combines with the main wave, the outgoing wave, so as to produce standing waves along the line.

Now, similar conditions apply to these antenna wires. In the case of a wire several wave lengths long, and having its remote end disconnected from anything except a mechanical support—that is, electrically disconnected or insulated or open or free—all the terms being more or less the same,—the abrupt termination at that remote end causes almost complete reflection of the electrical energy reaching the remote end.

Therefore, the use of an open ended wire, a wire having an insulated end, favors the production on that wire of standing waves because of the substantial reflection that exists in such an abrupt termination.

Because the velocity or speed of the current wave traveling along such an open wire is about the same as the velocity of the radio wave in space, the number of complete standing waves on a wire is almost exactly the same as the length [fol. 164] of the wire divided by the wave length. In that way a single wire 200 meters long, about 650 feet long would have developed in it four standing waves of 50-meter wave length.

Q. 57. In the type of antennas and feeding systems that we have in this case, what is the type of wave that is desirable on the transmission line?

A. On the transmission, you are anxious to get the traveling wave, the wave which conveys the maximum power with the minimum voltage and current, and which is the result of minimum reflection or zero reflection at the end of the transmission line.

Q. 58. And in the antenna portion of the apparatus, what type of wave is desired there?

A. In the antenna portion, these antennas use standing waves, that is to say, there is large reflection at the end of the antennas and the antennas are tuned so that the waves build up in the standing wave form.

Q. 59. All right, will you please proceed?

A. Lindenblad, on the first page of the specification, beginning in the paragraph starting at line 25, points out that a single antenna wire of the sort I have been discussing, a linear conductor, which is long as compared to the working wave length, will not radiate wave energy in the direction of the wire axis; and also that in a plane perpendicular to the axis of the wire, the radiation is substantially, or even entirely, cancelled out; also that the principal radiation from such a wire is in a double hollow cone which has the wire as its axis.

That is illustrated in Fig. 2, and further described on the second page of the patent, beginning at line 77. Your Honor will recognize that this Fig. 2 is a diagrammatic [fol. 165] representation of the distribution of radiation, and may be compared to the sort of diagram we have already mentioned here.

The wire itself is represented by the vertical line 8 in Fig. 2, and a cross section of the radiation is represented by the two conical figures numbered 10 and 12, the lines of the lobes extending upwardly and downwardly and to the left and to the right, being again proportional to the intensity of the radiation in the particular direction from the center to any point on the lobe pattern itself.

The thing may be visualized by considering that a single long wire transmits its radiation principally along lines which form two conical surfaces, the axes of the cones being the same as the axis of the wire. In other words, Fig. 2, being a cross section, would be rotated around the wire in order to represent the complete conical pattern in space.

That contrasts, because of the action of the length of the wire, with the distribution of the radiation from a short one-half wave length wire, which is described at page 2, lines 71 to 76, and is illustrated in Fig. 1. There the radiation is in the form of an annulus or doughnut surrounding the wire, and extending in the direction or in the plane perpendicular to the wire itself.

I discussed what these radiation patterns meant the other day, and I think I used this drawing, Fig. 1, as an example. Those same considerations apply to other directive patterns or other patterns of radiation such as Fig. 2, and such others as we have spoken of.

Q. 60. Now, Lindenblad states, at page 1, lines 45 to 48, that the radiation from the simple long wire is wasteful [fol. 166] of energy, and one object of his invention is to reduce the conical radiation so that it will consist only of concentrated lobes having axes in one plane. Will you please explain how he accomplishes this object?

A. He gets that result by making his antenna of two parallel wires, each several wave lengths long and by applying the electrical power to those wires so as to excite them in phase opposition, which I will explain. He illustrates such two-wire antenna in Fig. 3. There the two wires are marked 14 and 15. The other ends are connected to the generator 20 so that the power is supplied to both of the wires.

The result of making such a structure is to concentrate the conical radiation illustrated by Fig. 2 into four directions which are indicated by the four lobes marked 30, 32, 34 and 36 in this Fig. 3.

Because of the co-operation of the two wires the radiation above and below their plane, so to speak,—imagining them to be horizontal,—is largely cancelled out, and the bulk of the radiation remains in the plane of the wires themselves, but in these four directions within that plane, the four directions being indicated by the four lobes to which I have referred.

Now, this matter of supplying power to the wires so as to excite them in phase opposition simply means that the voltages and currents at corresponding points on the two wires at any particular instant are opposite in polarity, that is to say, for example, when the end of wire 14 is

charged positively, then the end of wire 16 will be charged negatively, and so forth, for other corresponding points and instants of time.

[fol. 167] To determine that particular condition, one must look at corresponding points of wire and look at them at the same instant. If, then, they have opposed polarities, they are said to be excited in phase opposition.

The way that is done is by connecting each of the two wires to the ends of a transmission line, such as No. 24 in Fig. 3, and the wires from that to the opposite ends of the generator, such as 20, so that the two wires of the transmission line are oppositely charged at any instant, and consequently the two antenna wires, being directly connected to them, are oppositely charged at any instant. That causes the antenna wires to be, in the technical phrase, "excited in phase opposition".

Under those conditions, then, the currents and voltages in the two antenna wires are at opposite polarity at any instant, and that results in the condition that the standing waves developed in the wires, the standing waves along the wires, will have opposite polarity at any instant.

What I have said about the distribution of the radiation around such a two-wire arrangement is explained by Lindenblad in some detail at page 2, beginning at line 105, and carrying over to page 3, line 10. Briefly it is that the antenna does not radiate in a direction normally or perpendicular to its plane, but tends to concentrate the radiation mainly in its plane, which in the case of Fig. 3 is the plane of the paper. At that same part of the specification Lindenblad explains the desirability of using open-ended wires, that is to say, wires having free or insulated far ends, so as to develop standing waves most effectively.

[fol. 168] I think that summarizes what the patent has to say as to Fig. 3.

Q. 62. After that, Lindenblad states, commencing at line 62, on page 1, that, referring to the arrangement of Fig. 3, "This arrangement, too, is wasteful of energy, and it is a further object of my invention to strengthen the radiation in one pair of opposite critical directions, while weakening the radiation in the conjugate pair of opposite critical directions." Will you please explain how he accomplishes this further object?

A. He does that by relocating the two parallel wires with respect to each other, that is to say, in this case by stagger-

ing the two wires. Fig. 4 shows such an arrangement, and that is described at page 3, lines 11 to 43. The result of moving one wire forward along its length, so to speak, and in that way staggering the two wires with respect to each other is to suppress two of these lobes of radiation illustrated in Fig. 3, thus the lobes marked 34 and 46 are shown in Fig. 4 as having been substantially minimized or even cancelled out. They are shown by the very small lobes 34 and 36 in Fig. 4.

The act of suppressing those two tends to emphasize the two other lobes in the conjugate or opposite angle across the axis, and this is indicated by the larger extent of the lobes 30 and 32 in Fig. 4.

By staggering the wires, then, Lindenblad produced an antenna system in which the principal radiation is in two directions along a single line, as illustrated by those lobes 30 and 32, and such an antenna system is called a bi-directive or bi-directional system. This type of radiation, long wire radiation, is a directive front and back or bi-directive radiating system made up of two simple straight long wires [fol. 169] having their remote ends open and excited as I have described in phase opposition.

Q. 63. Lindenblad then states at line 89 of page 1 that "the radiation has so far been reduced to a bi-directional radiation, and a further object of my invention is to make it unidirective". Will you please explain how he accomplishes that further object?

A. He points out immediately following the portion that you read that he provides another pair of simple linear conductors, and he describes that in greater detail at page 3, beginning at line 43, with reference to Fig. 5, which illustrates an arrangement of this kind.

In Fig. 5 there is a second pair of wires arranged beside the first pair, the first pair corresponding to the pair of wires in Fig. 4. The distance between the two pairs is an odd number of quarter wave lengths when measured along the direction of principal radiation. That is shown in Fig. 5 where the lobe 30 represents the direction of principal radiation and the distance between the two aerials is marked (2n plus 1) lambda over 4. That is simply the mathematical statement that the distance shall be an odd number of quarter wave lengths.

Lindenblad explains that the second pair of wires, like the first pair, is excited in phase opposition, that is, the voltages of each wire of the pair are opposite at any instant at corresponding points. But the currents in the second pair taken as a pair are displaced from the currents in the first pair in phase or in time by a quarter of a period, that is to say, by the time of a quarter of a cycle, which is usually spoken of as a 90-degree displacement.

[fol. 170] That double pair arrangement, as is indicated in Fig. 5, results in still further concentration of the radiating power into the single lobe marked 30 by the almost complete suppression or cancellation of radiation in the opposite direction represented by the backward lobe 32 in Fig. 4.

A radiating system of this sort, where the principal radiation is concentrated in one direction from the antenna (and of course we are speaking of the horizontal plane, it is a horizontal antenna), is called a unidirective or unidirectional antenna. Therefore, in Fig. 5 Lindenblad shows a unidirective radiating system which consists only of long wires in pairs, the wires of each pair being open-ended and carrying standing waves. The currents in each wire are produced by a generator which drives the wire of each pair in phase opposition, as I have described, and the two pairs of wires are so excited that one has currents one-quarter of a period or 90 degrees out of phase with the other pair.

That results in this unidirective system, and in my earlier testimony I pointed out the practical value of concentrating the radiation in a given direction when one is concerned with a point-to-point communication system.

Q. 64. Mr. Hogan, will you please summarize what you consider to be the basic features of the disclosure of this patent?

A. The basic features of this Lindenblad disclosure include a pair of wires, a pair of long wires excited in phase opposition and carrying standing waves, and the arrangement of those wires so as to concentrate the principal radiation in the plane of the wires.

Then he shows a modification which comprises reloca-[fol. 171] tion of the two wires one with respect to the other so that the lobes of radiation within the plane are combined in order to give a bi-directive radiating system.

Then as a further improvement, giving increased directivity, he describes the use of a second pair of bi-directive wires, each of them parallel to the similar wire in the first pair, and the two pairs being combined so as to produce a unidirective or single directional system.

I think that summarizes the basic features with which we are here concerned.

Q. 65. Now will you please state some of the practical advantages of the system shown and described in this patent?

A. First, the wire arrangement is simple and economical, both to construct and to maintain.

Secondly, the remote ends of the antenna wires are open or insulated and require no terminating apparatus connected to them.

Third, either the bi-directive or the unidirective radiation that I have discussed is obtained by means of structures that are less complicated and less expensive than the bi-directive or unidirective antennas that had been in use.

Fourth, the efficiency of the antenna system can be maintained without difficulty when the operating wave length is altered and without rebuilding the antenna, and

Fifth, the simple long wire antenna of this character has a high radiation efficiency, and by that I mean that a large percentage of the power applied to the antenna is radiated in the form of waves. In an antenna of this sort, radiation efficiency of the order of 90 per cent. or more is customary, [fol. 172] whereas in antennas like the Model A, the curtain type antenna, the complicated network of which we have spoken, an antenna efficiency of 50 per cent. or thereabouts, is about all to be expected.

I think that summarizes the advantages, that appeal to me, at least.

Q. 66. Now will you please refer to the second Lindenblad patent in suit No. 1,927,522, and explain the disclosure of that patent, particularly with respect to Fig. 2?

A. Like the first Lindenblad patent, this second Lindenblad patent No. 1,927,522 also relates principally to the radiating antenna itself, rather than to the transmission line that may be used to supply power from the generator to the radiating system.

The application for this second Lindenblad patent was filed December 24, 1928, which was about three months after the date of the application that resulted in the patent No. 1,884,006, which I have just considered.

The disclosure of Lindenblad's second patent represents another step of the RCA engineering group in simplifying the complicated and expensive directive antennas that are typified by the British beam or Model A, or other curtain types to which I have referred rather briefly, but which Mr. Hansell described in greater detail.

In Fig. 2 of this patent Lindenblad shows a V-shaped antenna. It is made up of two long open-ended wires that are excited in phase opposition and are supported so as to diverge from one another.

Those are the wires 2 and 4 of Fig. 2, their open ends being shown at 12 and 14 in the figure.

[fol. 173] Beginning at line 29 of page 1 of the specification, Lindenblad explains that an arrangement of this kind produces predominant radiation in the direction of the axis of the pair of conductors, and he has, earlier in the specification, at line 10, referred to the antenna as an exceedingly simple form of short wave antenna which will operate over a considerable range of frequency.

He points out, at lines 32 to 35, that in such an antenna reflections will cause a standing wave instead of a traveling wave, and that that will result in radiation sidewise from the antenna, thus there may be radiation not entirely along the axis of the antenna system.

However, in spite of such sidewise radiation he states that the radiation in the preferred direction is considerably greater than that which is obtainable from a simple doublet or a half wave di-pole, for example.

Now we know from later study of antennas of this type that if one sets up a pair of wires, each pair five to ten wave lengths long, and if one spaces the open ends of those wires by about one-fifth of their length, there will be produced a received signal in the desired direction of transmission that is as much as three times as powerful as one would get from the same amount of power applied to a half wave di-pole antenna.

Those dimensions of five to ten wave lengths long and having a spacing at the open end in the neighborhood of one-fifth of the wire length, are suggested by Lindenblad at page 2 of the specification, beginning at line 116.

This Fig. 2, to which I have been referring, shows schematically or diagramatically by means of a rectangle marked [fol. 174] 16 and having the legend, "Impedance Matching Device", that the wires may be used with impedance matching of the sort that I have discussed in connection with the earlier Carter patents.

Lindenblad points out beginning at line 116 of page 1, that reflection may be neglected if the transmission line is short; but if the transmission line is long, and the antenna is relatively small, so that only a small portion of energy is radiated, it may prove desirable to employ an impedance matching device between the transmission line and the antenna as is indicated by the impedance matching unit 16 shown in Fig. 2.

I have read the portion of the specification carrying over to line 3 of page 2.

Thus, if the antenna is not so long that the energy is largely or almost entirely radiated from it, without reflection from the ends, the impedance matching device may be desirable.

The principal advantages of this Lindenblad diverging long wire antenna are its simplicity, its cheapness, its operativeness over a considerable range of frequencies, and its ease of erection, maintenance and adjustment. As he describes it in this patent, it had not attained its final form or its most efficient form, and further theoretical work and experimental development were necessary before the modern V type antenna was produced.

Lindenblad recognized that his directive antenna wasted power due to radiation in undesired directions, and he proposed to remedy that, as he says, at page 1, line 38, by "as a refinement reducing the standing waves in the wires". Reduction of standing waves would reduce sidewise radia- [fol. 175] tion, but not sufficiently to improve the antenna efficiency, or rather the antenna directivity, because we are concerned with directive efficiency at this point, sufficiently to make the radiating system meet the rigid requirements of commercial service.

It remained for Carter to discover that this reduction of undesired sidewise radiation could be obtained more effectively, by taking advantage of a new co-relation between the length of wires and the length of waves, and the angle between the diverging wires. I will explain that in more

detail in connection with the third Carter patent. Nevertheless, the V antenna in its most highly developed form and as it is used, both by the defendant at Sayville and by the RCA Communications organization at Rocky Point and elsewhere, does have these features and advantages, which I have described in connection with the disclosure of the second Lindenblad patent, 1,927,522.

Q. 67. Have you had prepared under your direction and supervision a scale model of the defendant's antenna No. 8, as described in Plaintiff's Exhibit 7 in this case?

A. Yes.

Q. 68. And this apparatus, one end of which stands on one table and the other ends stand on another table, is that the apparatus?

A. Yes, that is the model.

Q. 69. Except that the transmission line is not connected to it at the present moment?

A. Only the end of the transmission line, nearest the apex of the antenna is on the model as it is now set up; the full transmission line would run off some distance to the right.

Mr. Blackmar: I offer the model in evidence.

[fol. 176] (Marked Plaintiff's Exhibit 29 in evidence.)

Q. 70. Mr. Hogan, will you please refer to the third Carter patent in suit, No. 1,974,387, and state first, in general, what it relates to?

A. This patent, which we are calling the third Carter patent, shows a new antenna system, which is the modern and highly efficient form of V antenna. It involves the latest of these improvements worked out by the RCA engineering group, and uses the basic disclosures of both of the earlier Lindenblad patents. The application for this patent was filed June 11, 1930, about a year and a half later than the application for the Lindenblad diverging wire antenna, patent No. 1,927,522.

Carter's specification in its opening paragraph states the primary object of his invention to be the provision of a simplified and highly efficient antenna system utilizing standing wave phenomena.

Q. 71. At lines 15 and 16 on page 1, Carter states that the present invention makes use of certain phenomena which

he has previously described as known at that time. Will you please explain these phenomena, and how he utilizes them, referring particularly to Figs. 2 and 3, and if you desire, to the model Plaintiff's Exhibit 29, and also state what he accomplished by the utilization of these phenomena?

A. The phenomena to which he referred are those relating to the symmetrical, double cone of radiation from a single long wire, which are illustrated in figs. 1-a and 1-b of this third Carter patent.

This action of a single wire was explained by Lindenblad in patent 1,884,006. Fig. 2 of that Lindenblad patent resem- [fol. 177] bles closely this Fig. 1-A, of the third Carter patent. Both of those figures show the principal cones of radiation around a single long wire of that kind.

Beginning at line 17, on page 1, Carter describes his antenna in its most simple aspect, as being made up of two relatively long, open ended wires, excited in phase opposition, carrying standing waves throughout their lengths, and being placed at an angle to each other in a single plane.

He further points out that the angle from each wire to the bisector of the angle between the two wires, corresponds generally to the angle of the principal cone of radiation of one of the wires.

With a V arrangement of that kind, the principal radiation of a pair of wires then takes place bi-directionally along the line of the bisector and principally in the plane of the wires.

Figs. 2-A and 2-B and 2-C of the patent which are described further at page 2, beginning line 29, illustrate a structure of this kind.

It may be easier to visualize this arrangement by referring to the model, Exhibit 29, because that is built in three dimensions, rather than simply being a drawing on a sheet of paper. This simple V antenna of Figs. 2-A, 2-B and 2-C is represented in the model by either one of the two V's.

The wires are long, they are energized in phase opposition by their connection to the transmission line and generator, as I explained in connection with the first Lindenblad patent. They have standing waves as favored by the use of open-ended or insulated wires, unconnected to anything, that is the far ends of the antenna, and they are in a single [fol. 178] plane, the two wires of each V, and located at an

angle such that the principal radiation is along the bisector of the V.

Thus Carter utilized Lindenblad's diverging wire antenna, and further discovered that it was of great importance practically to place the wires of the antenna at least approximately at a referred angle to each other, and further that that angle depended both upon the wave length used, and the physical length of the wires comprising the V.

Carter found that by using that preferred relation between those three factors, wave length, the wire length and the angle between the wires, that with standing waves on the wires, it was possible to obtain unexpectedly high increases of signal power, due to the directivity of the system.

For example, with Carter's arrangement a single V having wires from five to ten wave lengths long, gave signal multiplications of from 6 times up to about 12 times that which would be had from the standard di-pole using the same amount of power.

Q. 72. At what point?

A. At the desired receiving point.

That very substantial and valuable increase in effectiveness came about because of a surprisingly great reinforcement of the signal transmitted in the direction of the bisector, which was accomplished by a reduction of wasted radiation, and that reduction, in turn, being accomplished by a surprisingly great cancellation in all directions both horizontally and vertically around the antenna system.

Carter's rule corelating the angle represented by Alpha in Figs. 2-A and 2-B of the third Carter patent, corelating [fol. 179] that angle with the wave length used, and with the length of the wire, taught how this principal radiation from the long diverging-wire standing-wave antenna could be concentrated not only in the plane of the wires, as occurred with the Lindenblad arrangement, but also still more effectively into a bi-directive beam within that plane.

In that way, Carter's directive antenna obtained the high efficiency and directivity that he refers to at line 3 and lines 21 and 22 of page 1 of the specification.

Now, on page 2 of this third Carter patent beginning at line 47 and continuing to line 77 or 78, Carter explains how the preferred angle for a given wave length and given length of wire may be found from the equations that are printed at lines 60 and 70 approximately.

The first of those equations applies when the side wire of the V has a length which is equal to an odd number of half wave lengths, as is stated at line 57, and the second equation applies for side wires, having an even number of half wave lengths in their total length.

Carter also points out (and for that, I refer to page 1, lines 29, and following), that he has found the preferred angle for a pair of wires of any specified finite length in relation to the wave length, when they carry standing waves. In that way he explains not only the use of V antennas whose side wires are equal in length to any part and approximately an exact multiple of the half wave length, either even or odd, but also the use of wire length of any intermediate value between the even and odd number of half wave lengths. [fol. 180] At page 2, line 83, he gives the equation for determining the preferred angle for any particular wire length, and Fig. 12 of the patent is a chart from which it is easy to read the preferred angle for any length of side wire, from one to 14 wave lengths, and, of course, that more than covers the range of lengths that is in common use.

For example, if the length of one wire of the V, as stated along the bottom of Fig. 12, is six wave lengths, one may run up the verticle line above the No. 6, to the intersection with the curve, and then across to the left, where we find that 20 degrees represents the angle Alpha, or half the angle between the wires, and therefore the total included angle represented and preferred for a wire length of six wave lengths would be twice that or 40 degrees.

The simple form of the single V diagrammatically illustrated in Figs. 2-A, 2-B and 2-C, then comprises the two radiating wires marked A and B, each one of them located approximately at the preferred angle, from the bisector which is indicated by the lines X-X of these figures. The separated ends, the remote ends of those wires are insulated or free or open, as I have said, so as to promote standing waves on the antenna wires, and the ends of the wires at the apex of the V are excited through the transmission line in phase opposition.

Q. 73. Now, will you please take up Fig. 4 of this patent, and explain the disclosure of the patent with respect to it?

A. Yes. Fig. 4 is a rather pictorial illustration of a practical application of the arrangement of Fig. 2 of the patent. The V wires in Fig. 4 are marked A and B, and

[fol. 181] the connections to the transmission line 24 are marked 26. In Fig. 4, in the arrangement shown there are two V's one arranged above the other, the upper one being marked A-B, and the lower one A'-B'.

That particular arrangement results in a further concentration of the waves more nearly into a single horizontal plane, as Carter explains at page 3, line 24, but double layer V's of that kind are not used by the defendant, so far as I know.

Even though this be a two-story or double layer V in Fig. 4, it is a single V antenna, from the view-point of its horizontal directivity, which is what we are concerned with at the moment, because the radiation from an arrangement like that of Fig. 4 is a bi-directive. Such bi-directive radiation is shown in Fig. 3 of the patent, and that applies to single V's whether they are in the simple form of Fig. 2 as represented by one of the V's of the model, Exhibit 29, or whether they are represented by the vertically-disposed pair form of Fig. 4.

In other words, the simple antenna element of Fig. 2-A or 2-B or 2-C, or the simple V corresponding to one of the V's in the model, or the two-story V of Fig. 4 has bi-directive radiation, of the sort generally represented by Fig. 3 of the patent.

Q. 74. At page 1, lines 43 to 44, Carter states that "A further object of the present invention therefore is to provide a unidirectional arrangement." Will you please state how he accomplishes this?

A. Yes. Carter does that by setting up a second similar pair of V wires, the individual wires of the second V being parallel to the corresponding individual wires of the first V; and he sets up this second V, in a position which is determined by measuring a distance equal to an odd number [fol. 182] of quarter wave lengths along the bisector line. Fig. 5 of the patent shows a double V antenna giving unidirective radiation and made up in that way. The two horizontally separated V's in Fig. 5, one, that is the rear, being marked a and b, and that to the right being marked A and B, are said to be separated by a distance of 2¼ wave lengths, which is nine quarter wave lengths, or an example of the odd quarter wave length spacing.

The model also represents two such parallel V's arranged with an odd quarter wave spacing, in this instance, the

distance being three-quarters of a wave length along the line of the bisector.

Fig. 5 of the patent shows a two-story arrangement, each V having below it a second V, for vertical reinforcement, as I explained in connection with Fig. 4, but so far as I know that second story is not used in either the single or the double V's by the defendant.

There is another variation of the double V arrangement shown in Fig. 11, which is practically the same as Fig. 5, except that each of the V's has four stories, located vertically, so as to give still further concentration of the radiation with respect to the veritcal plane.

Any one of these double V arrangements, that of Fig. 11, that of Fig. 5, or that of the model, has generally the radiation pattern in the horizontal plane which is shown by Fig. 6 of the patent. That is to say, all of them give primarily unidirective radiation along the bisector line.

Similarly the use of two V's in this way, so that the radiation in the desired direction is increased and that in the rearward direction decreased, results in twice the power [fol. 183] gain for signals in the desired direction of principal radiation than would be had from a corresponding single V, having the same dimensions.

That doubling of the power gain takes place whether one compares two single V's as in the Model, Exhibit 29, or two two-story V's as illustrated in Figs. 4 and 5 of the patent. Fig. 4 is a two-story single V, and Fig. 5 a double two-story V. What I mean is, if the dimensions of the V's are the same, Fig. 5 will give double the gain of Fig. 4, even though two-story elements are considered, just as, in the case of the model, doubling the gain is had in the preferred direction from two single V's as against one V. We have nothing to compare Fig. 11 with in the way of a single V, but we could imagine a four-story single V, and in that case Fig. 11 would give double the gain of the four-story single V where the two had the same fundamental dimensions.

Beginning at line 68 on page 3 of the specification, and further beginning at line 9 on page 4, the first reference being with regard to Fig. 5 and the second with regard to Fig. 11, Carter gives further details of these double V arrangements and includes an explanation of the preferred phase or excitation difference of 90 degrees as corresponding to an odd number of quarter periods.

The preferred spacing for the two sections, which are often called the antenna and the reflector, is given as two and one-quarter wave lengths when the wires are from six to twelve wave lengths in length.

It is also pointed out that where wires are shorter, say, from three to four wave lengths in length, the spacing be- [fol. 184] tween the pairs of wires along the bisector may be one and one-quarter wave lengths or less.

Q. 76. Will you please refer to line 125 of page 3 of the patent and explain that mathematical expression that occurs there, and its application to these antennas?

A. That is a general statement of the phase difference between the units or sections for the preferred condition, and simply states that the spacing measured in wave lengths should correspond with the phase difference in periods. For example, if the spacing is one-quarter of a wave length, the phase difference should be 90 degrees, and as the spacing is increased to three-quarters or five-quarters, the preferred phase relation is shown to be either plus or minus 90 degrees, which amounts to the same thing because it is a relative phase difference. The expression at line 125 is used in connection with Fig. 9 of the patent, but is sufficiently broad mathematically speaking to apply to the general arrangements we have been discussing.

Fig. 9 is an arrangement that I understand is not involved here.

I might also point out that Carter says that following this rule gives the concentrated unidirectional propagation in either direction, depending on whether the current in one unit leads or lags that in the other, that is to say, whether the relative phase of the currents is plus or minus 90 degrees, as compared to the spacing.

Q. 77. So that, according to each of those arrangements, the unidirective radiation from an antenna of this type may be either from the apex of the antenna toward the open ends in the direction of the bisector or in the direction of the [fol. 185] bisector from the open ends through the apices?

A. Yes; you have complete control of that 180-degree reversibility of direction by changing the relation between the feeding of the two wires. For example, by transposing the transmission line between the first pair and the second pair, or by feeding at the inside pair first, instead of at the outside pair.

Q. 78. Now will you please explain the methods of tuning these antennas and matching the load resistances to the surge impedance of the transmission lines, as shown, for example, in Fig. 2C of this patent, and in other figures?

A. Fig. 2C shows a U loop composed of the conductors extending from 16 to the cross bar 14, and having taps at the points 18. The arrangement is suitable for tuning the antenna system and matching its impedance to the surge impedance of the transmission line which supplies the radiating system with power.

The arrangement is described and its construction and adjustments pointed out at page 2, beginning at line 116 and running on down through the next few paragraphs.

Briefly, in order to tune an antenna system composed of the wires AB, the total effective or electrical length of the two radiating wires plus whatever is connected to the apex end is made equal to an odd number of half-wave lengths, or to say it in another way, each side is made equal in electrical length to an odd number of quarter-wave lengths.

Carter points out, at page 3, beginning at line 8, that it is the length of the V-shaped radiating part of the antenna [fol. 186] system, not including the length of the wires in the loop or tuning means or transmission line, which is to be used in applying the rule or the chart of Fig. 12 to determine the preferred angle.

When the antenna is tuned by adjustment of the connections 14 governing the position of the cross connector and of the taps 18 in Fig. 2C so as to get the proper lengths in the different parts of the system, then the inductance and capacity effects are balanced out and the antenna acts at the points 18 as a pure resistance load. The value of that resistance load is matched to the surge impedance of the transmission line by the tapping of the transmission line into the connections to the radiating system at the proper points which are marked 18 in this Fig. 2C.

That method of tuning and matching is generally similar to the arrangement of Fig. 3 of the second Carter patent No. 1,909,610. The inductance 12 in the figure of the second Carter patent is replaced here by the equivalent inductance of the loop ending in the cross bar 12 of the third patent.

A short loop of that kind constitutes an inductance made up of a relatively large half turn of wire instead of one

made up in the more concentrated form of a coil having relatively small turns.

Q. 79. Now will you please refer to Fig. 7 of this patent and briefly point out what it means?

A. Yes.

Fig. 7 shows the power distribution in the vertical plane of such a horizontal V antenna without considering any effect due to ground. That vertical distribution is a pattern [fol. 187] which is made up in exactly the same way as the horizontal power distribution patterns that I have already described, as for example, Figs. 3 and 6, but instead of showing the horizontal directivity, which is the thing that determines in what geographical direction the signal is projected, this Fig. 7 illustrates the vertical directivity or directivity as referring to a vertical plane.

It has significance in connection with the efficiency produced by concentration, because within limits the sharper the concentration is in the vertical plane the more power is available for projection in the desired direction.

In the operation of a double V antenna such as we have represented by Model, Exhibit 29, the principal radiation of the antenna itself is in the geometric line of the bisector, that is to say, a horizontal beam is produced in so far as the cooperation of the antenna elements themselves are concerned. If a pair of V's of that kind were in space so that no conducting bodies were in their neighborhood to interfere with the direction of propagation, the energy would be concentrated along the geometric line of the bisector, speaking both vertically and horizontally. In practical use the antennas are set up on poles, usually about 80 feet high. Carter says at page 3, lines 58 and 59, that 80-foot poles or masts may be used to support the wires, and that is a common length. In that case, with the range of wave lengths that is common in short-wave transmission over great distances, the wires are, generally speaking, from three-quarters of a wave length to a little over one wave length above the ground. In a case of that kind, if one considers [fol. 188] distances a little way beyond the antenna itself and in the direction of propagation, it is not hard to see that following a diagram such as that of Fig. 7, some energy is projected downward to the ground, not directly along the line of the bisector, the geometric line of it. That energy going down from the end of the antenna is reflected from

the ground at an equal angle, and depending upon the character of the ground its phase is changed. The reflected energy combines with the energy radiated from the antenna itself and goes off into space, and the practical result of a set-up of this kind is that the beam from the antenna, instead of being projected along the geometric line, is actually tilted up at some distance from the antenna.

That, in practice, is a very good thing for these short wave lengths, because, in the first place, it has no effect on the horizontal directivity with which we are concerned, or the thing that makes the signal go to San Francisco, or something of that kind; and in addition to having no adverse effect upon the important horizontal directivity, it takes greater advantage of one of the most peculiar things about short-wave transmission, namely, it projects the waves up at an angle which is of reasonable value for their reflection down again from what we call the Heaviside layer in the upper spaces, perhaps 100 or 120 miles above the earth's surface, it reflects them down from that layer onto the receiving point; in other words, the effect of each of those conducting or partially conducting bodies, if we may call the Heaviside layer a body, is to change the direction of waves, and at a great distance one would imagine if he didn't know better that the received waves were coming [fol. 189] down from the heavens above instead of from a point on the earth's surface.

I think that that is all that follows from the showing of Fig. 7 and that we need to consider here, the important thing being to bear in mind that there is no effect of this vertical distribution upon the horizontal directivity, practically speaking, and that the pattern of Fig. 7 in the vertical plane, with ground effect neglected, does not represent the case where reflection from the ground beyond the end of the antenna causes a reinforcement of reflected and direct waves from the antenna so as to give a beam tilted upwards at perhaps 10 degrees instead of along the geometric line of the bisector.

Q. 80. Mr. Hogan, if the principal radiation were along the geometric line of the bisector, what would be the effect with respect to the ability to receive that at a distance away from the antenna in view of the curvature of the earth?

A. You would have to hope that enough energy would reach the Heaviside layer at a very great distance measured practically tangentially to the earth's surface at the point of origin for reflection down to your distant station. What would occur, I cannot say.

Q. 81. Mr. Hogan, will you please state some of the practical advantages of the type of antenna described in this patent?

A. First, the exceptionally high directivity per unit of the antenna system; second, its low cost of erection and maintenance; third, its simplicity and stability of adjustment; fourth, the fact that it utilizes standing waves effectively and that there is no need to minimize them either by having [fol. 190] exceptionally great length or by using terminal resistors; fifth, its adaptability to successful use with a wide range of lengths of wire and lengths of wave; sixth, its high radiation efficiency, which is usually 90 per cent or 95 per cent, or even more; and seventh, that if the side wires are longer than about six wave lengths in length, it has a relatively high directive efficiency for a considerable range of wave lengths in any one structure, that is to say, that the preferred angle becomes less critical for the longer wires.

I think those are the principal features.

Q. 82. Have you marked a copy of Plaintiff's Exhibit 23, the map of the Sayville station, with the numbers of the antennas as those antennas are identified in the stipulation?

A. Yes; in addition to the antenna numbers, I have also placed on the map the identifying call letters of the transmitters used with these antennas. I might point out that in the case of antennas Nos. 2 and 3 I have put down two call letters because those antennas are described in two forms, first, as originally built, and second, as rebuilt. The upper call letter in each case corresponds to the original use and the lower one to the use as rebuilt.

Mr. Blackmar: I offer that in evidence and suggest that it be marked Exhibit 23A.

(Marked Plaintiff's Exhibit 23A in evidence.)

Q. 84. Mr. Hogan, will you please describe generally this Defendant's antenna No. 2, in its original form, as covered in the stipulated description and the drawing annexed thereto, of which the chart now before you is a copy?

[fol. 191] A. At the time the suit was filed, the No. 2 antenna located north of the tall tower and buildings in the center of the property, was, as is shown by the sketch attached to Exhibit 10. Dimensions are given in part on the drawing, and in further detail in the tabulation, Exhibit 13.

The supporting poles and insulators and such details of structure are not illustrated in this chart, but only the radiating wires of the single V, which extend a distance of 517 feet from the open ends A and B to the apex C and D.

The angle included between the wires is shown on the chart as 35 degrees. The two wires are in a horizontal plane, which it is difficult to see from the drawings, the arrangement being like one of the pairs in the model, Exhibit 29.

The fact that three points of the V system are each indicated as 80 feet above ground is perhaps enough to define that horizontal placing.

The drawing shows also the transmission line which runs from the antenna downward and then more or less horizontally a distance of about 750 feet from the bend at the point IJ to the transmitter house, and vertically a distance of 67 feet, according to Exhibit 13, from the bend IJ to the antenna apex CD.

At the time the suit was begun this antenna was being used with a transmitter using the call letters WML, which are shown at the top of the chart, and a wave frequency of 14,740 kilocycles, which corresponds to a wave length of 20.35 meters, or only a little over 66 feet for a complete wave in space.

One of its destinations, according to Exhibit 10 was Vienna, Austria. The great circle bearing of Vienna from [fol. 192] Sayville is 49.74 degrees east of true north, and by that, of course, we mean simply the bearing measured with true north as zero degrees, and then rotated 49 odd degrees in the easterly direction.

That same bearing system is used, even though one goes all the way around to 280 degrees or to 300 degrees east of north. While smaller numbers would be involved if we went west of north, it is easier to have uniform numbers for reference.

The direction of the bisector of the antenna, which is called its directivity, and which defines the horizontal di-

rection in which the maximum radiation occurs when taken from the center of the antenna towards the apex, that is to say, to the left in the diagram, is 49.75 degrees east of true north, almost exactly that of the Vienna Great Circle bearing.

The antenna is also referred to in the stipulated description, Exhibit 10, as having been used for sending messages to Copenhagen, which has a bearing 43.36 degrees, to Budapest, the bearing of which is 49.52 degrees east of north, and Vatican City, the bearing of which is 57.9 degrees east of north.

The tabulation, Exhibit 13, also part of the stipulation, is arranged on two sheets in columns, one column corresponding to each antenna, and by reference to that and to this chart, one can find in the second column all the principal dimensions of the No. 2 original antenna, including call letters, wave length, destinations, and bearings, the angle east of north of directivity, and the mechanical dimensions and arrangements.

The tabulation gives the same data so far as it is known [fol. 193] for all eleven antennas, and the two additional forms of antennas, 2 and 3 rebuilt. The original antenna No. 2, like all of these V antennas, was to be supplied with high frequency power at its apex CD, because the radiating system begins there, and extends to the open ends AB.

CD is at the total distance of about 819 feet from the transmitter, measured along the transmission line, and that distance corresponds to something over 12 wave lengths from the power house, where the high frequency electrical power is generated, or the transmitter proper is located.

That distance from the transmitter to the apex of the antenna was, of course, bridged by the transmission line as shown in this Exhibit 10 drawing.

The stipulated description, Exhibit 10, states that the loop circuit KMNL was so adjusted when the antenna system was installed that an approximate impedance match was provided at the pair of points KL along the transmission line, whereby the energy was efficiently transferred across that pair of points, and reflection from there towards the transmitter was reduced.

That means that the effective resistance of the antenna system, taken in connection with the section of the transmission line from KL up to CD and with the loop KMNL has been made so that at the points KL it was equal within

practical limits to the surge impedance of the transmission line, from the transmitter to the points KL.

If that were not so, there would be an equivalent of an electrical discontinuity KL, and the energy would not be efficiently transferred across those points into the antenna [fol. 194] and, consequently, the wave energy would be reflected towards the transmitter, and therefore the stipulation, or rather, the description, Exhibit 10 attached to the stipulation, describes that there has been made the adjustment necessary to attain the condition described in the first Carter patent, in which reflection on the transmission line is so minimized as to make it substantially of electrically infinite length in the way that phrase is used in the patent; that is to say, to make it of the high efficiency which is desired, and which I explained in discussing the patent.

Referring to Fig. 1 of the patent, the generator 14 in the patent drawing, and the transformer 13-12, together, correspond generally with the transmitter in the drawing of Exhibit 10.

The two wire transmission line which has the reference number 10, in Fig. 1 of the patent, corresponds to the two wire transmission line extending from the transmitter to the apex points CD, by way of the match points KL in the drawing of antenna No. 2—original.

The impedance matching transformer, marked 11 and 2 in Fig. 1 of the patent corresponds in function to the impedance matching circuit KMNL and KL to CD in the drawing of antenna No. 2. And the antenna 1 and the ground 6 correspond in their connections in the patent, with the radiating wires AC and BD of the antenna drawing.

I might point out that although the electrical distance from the transmitter to the antenna apex was about twelve wave lengths in the original antenna No. 2, the distance from the transmitter to the match point KL is something less than that, being set back by the 67-foot riser and about [fol. 195] 30 feet horizontal distance, so that the distance from KL to the transmitter is about 720 feet or nearly 11 wave lengths from the transmitter.

Q. 87. Will you explain how the impedance match is obtained in this particular antenna, and compare the impedance matching circuits with those described in the second Carter patent, Plaintiff's Exhibit 2?

A. Generally speaking, the way the impedance match that I have described was attained or provided so as to

get the high efficiency transmitting line was by adjusting the position and the length of the wires KM and LN, and the position of the cross connection MN as described in the stipulated exhibit 10.

The distance from CD by the way of IJ to the point KL, or, in other words, the position of KL along the transmission line determines the length of the transmission line section from KL to the apex of the antenna at CD, and the half turn loop KMNL provides a shunting reactance across those points of the transmission line, and the amount and character of that shunting reactance is determined by the position of the cross connection MN along the side wires of those extensions from the transmission line.

In this case the reactance at the point KL provided by the loop KMNL is an inductive reactance. In this antenna No. 2 the transmission line has uniform characteristics all the way from the transmitter to the apex point CD. And if the system were left with only that line as initially run, it would not be matched, the transmission line would not have the high efficiency resulting from a reduction of standing waves upon the transmission line.

[fol. 196] The antenna would not even be tuned and, of course, its load resistance would not be the same as the surge impedance of the transmission line. That is saying, perhaps, the same thing in another way, but we have three or four ways of looking at this final, this same final effect.

The surge impedance of this line is about 600 ohms, and that results from the fact that the transmission line is made up of No. 6 wires, spaced 12 inches apart in accordance with the stipulated description. The load resistance of an antenna like this No. 2 original form antenna might be anything from a few hundred ohms up to several thousand ohms for the wave length that is being used, and how much that resistance component or effective resistance would amount to, would depend upon at what point along the antenna wires (or where the standing waves exist) one made the measurement.

As a general rule, the minimum value of resistance occurs at points that are quite near to an odd number of quarter wave lengths from the remote or open antenna ends, and the high values of resistance come at points that are close to an even number of quarter wave lengths from the open ends.

Now, in this instance, we have a distance of 517 feet from AB to CD, that is to say, the length of the side wire, and that is within a few inches of seven and three-quarter wave lengths, or 31 quarter wave lengths, that distance for that 66.77 feet wave, I think, being 517.39 feet. Those points CD, therefore, are located substantially at an odd number of quarter wave lengths, 31, from the ends of the antennas, [fol. 197] the open ends of the antennas; and therefore the antenna resistance at the points CD is of the order of 100 or 200 ohms, the lower values.

Consequently, it is considerably lower than the surge impedance of 600 ohms, that is characteristic of the transmission line.

Now, that condition where the load resistance is less than the surge impedance, corresponds to either case 1 or case 3 of the tabulation in the second Carter patent 1,909,610.

For case 1, capacity would be used across the line, and in case 3 inductance would be used across the line. Here the defendant has used an inductive loop across the line, and consequently the situation corresponds to case 3 of the tabulation at page 2 of the Carter patent, where he points out that the inductive reactance in case 3, should be connected across the transmission line at a point which would provide a line section length, that is the length between KL and CD in this case, which is greater than one quarter but less than one half wave length, or equivalently, as he pointed out, in an even numbered quarter wave length section of the transmission line, measured back from the load to the transmitter.

I have made a more detailed chart of this matching system for original antenna No. 2, which shows that the distance between CD, the apex, and KL, the point of connecting the inductive reactance, being 97 feet in length, comes more than one and a quarter but less than one and a half wave lengths from the apex, so that the points K and L are in the sixth quarter wave section measured toward the transmitter from the point CD.

[fol. 198] This diagram is, so to speak, an enlargement of the central portion of the drawing of Exhibit 10, but is all laid out in one plane, so as to make the relative dimensions easier to compare.

The corresponding points are lettered in the same way. For example, the apex of the V section is marked CD, points IJ, 67 feet from CD and 37 feet from KL, are marked along

the horizontal lines and KL and the loop itself are also shown.

That of the load resistance is less than the surge impedance of the line and is indicated at the right, and so forth. The amount of reactance, of inductive reactance connected across KL can be varied, of course, by changing the size of the half turn loop. If the side wires of such a pair were open and had no cross connection like MN, they would act like the plates of a condenser and so supply capacitive reactance. When they are closed in this way by the pair LN with the connections, and where the lengths are less than a quarter of the wave length used in the antennas we are considering here, they provide an inductive reactance, and that amount depends on the size of the loop, that is to say, upon the length of the side wires, K to N and I to N.

In antenna No. 2, that includes a half turn loop, 17.7 feet long, after its adjustment, and that was the measure of inductive reactance provided by the loop. I have already pointed out that these adjustments are described in the stipulated description, Exhibit 10, as providing an approximate impedance match at KL and resulting in a reduction of the reflection of waves from KL towards the transmitter.

The variable inductive reactance connected in the sixth [fol. 199] quarter wave section, instead of in the second quarter wave section is one of the cases of a more remote connection described at the portion of the specification beginning at line 60 on page 1.

The value of the inductive reactance provided by the loop is chosen so that in cooperating with the electrical constants of the length of the line section from KL to CD and further in cooperating with the value of the load resistance of the antenna at about the points CD, there is attained the final result of a practical impedance match such as will reduce reflection from the points KL. The practical result of that is the long, high efficiency transmission line of the first Carter patent, but provided by the specific matching arrangement described in the second Carter patent.

Mr. Blackmar: I wish to offer in evidence the sketch of the impedance matching system of antenna No. 2 original referred to by the witness in the course of his last answer.

(Marked Plaintiff's Exhibit 30 in evidence.)

Q. 88. Mr. Hogan, in connection with this impedance matching system of this particular antenna, is there anything besides the load, which, as I understand it, is represented by the antenna, and appears at point CD; and the portion of the transmission line between the load and the parallel connected reactance, that portion being the wires CK and DL: and the reactance itself, which I understand is the U loop KMNL, which enter into the matching circuit?

A. No, there is nothing else; those three things, the load, the line section and the reactance connected across the line [fol. 200] comprise the matching system.

Q. 89. In the system of this antenna are there any serially connected impedances in the transmission line between the source and the load?

A. No, there are none.

Q. 90. Now will you please describe other details of that antenna system No. 2 in its original form.

A. The WML original antenna No. 2 is a directional short wave antenna and it is made up of two wires, AC and BD, which are simple linear conductors. Those wires are long relative to the working wave length, the distance AC and the distance BD being 517 feet, or very nearly seven and three-quarter wave lengths. The two wires are in a single plane and together they lie on one side of the connection point CD. The wires of the WML antenna have insulated or open ends at AB, and that favors the development of standing waves by reflection on the antenna wires. In fact, the stipulated description, Exhibit 10, points out that waves are intentionally reflected between the antenna ends AB and the point MN by way of KL. That reflection provides the desired standing waves along the wires AC and BD.

The two wires are coupled to the transmitter through the transmission line so that they are excited in phase opposition, as is also set forth in the stipulated description, and as a result of that, the standing waves have opposite polarities at corresponding points on the two wires at any particular instant.

The principal radiation from the No. 2 antenna is concentrated in the plane of the wires. Further, the radiation from antenna No. 2 is concentrated by the strengthening of one pair of lobes and the weakening of another pair of [fol. 201] lobes of radiation from each of the two wires.

As a result of that, the antenna No. 2 system has bi-directional radiation. As I have pointed out, I think, the destination points lie almost exactly or approximately along the line which bisects the angle of the V antenna No. 2.

Q. 91. Will you please compare the system of this antenna No. 2 in its original form with the disclosure of the second Lindenblad patent in suit, Plaintiff's Exhibit 4, with particular reference to Fig. 2 thereof?

A. Original antenna No. 2 also embodied the features of the Lindenblad patent 1,927,522, Fig. 2. As in the patent, the long open-ended wires were excited in phase opposition, as I have already explained, and as in the Lindenblad patent, they gradually diverged as they were extended from the end of the transmission line CD towards the open ends AB. Thus they were like the arrangement of Fig. 2 of the Lindenblad patent.

The length of seven and three-quarter wave lengths, very nearly, is within the range of from five to ten wave lengths, which is suggested by Lindenblad at page 2, lines 120 and 121.

The axis of the WML antenna system lay in the general direction of principal radiation, the destination points being almost exactly or approximately on that axis, and the desired radiation therefore taking place in the direction specified by Lindenblad in the middle of the first column of page 1.

Q. 92. Will you please compare the system of this antenna No. 2 in its original form with the disclosure of the third Carter patent in suit, Plaintiff's Exhibit 5?

A. The original antenna No. 2 used with call letters WML [fol. 202] corresponds generally to the simple V shown in Fig. 2C of the third Carter patent. The WML antenna, like the Carter antenna, was composed of long linear conductors carrying standing waves, and it was disposed substantially at the angle taught by Carter, so that the radiation occurred principally along the direction of the bisector of the angle, as illustrated generally in Fig. 3 of the Carter patent.

Antenna No. 2 corresponded generally to the arrangement of Fig. 4 of the Carter patent, except that it did not include the second vertical concentration wires A′ and B′. The included angle of original antenna No. 2 was 35 degrees, as is shown in the diagram of Exhibit 10, and therefore

the angle between each wire and the bisector was 17½ degrees.

From Fig. 12, the chart of the Carter patent, based upon the formula that he gives at line 85 of page 2, the preferred angle for maximum radiation for wires 7.74 wave lengths long would be 17.8 degrees. If the angle of No. 2 antenna had been 17.8 degrees instead of 17.5 degrees, as it was stated to be in the stipulated description, the power multiplication of the signal in the desired direction as compared to the signal which would be received from a half wave dipole antenna with the same power, would have been 9.9 times, whereas with the 17.5 degree angle, the power gain was 9.8 times. Therefore the power gain percentage for the angle actually used in antenna No. 2 original, was approximately 99 per cent. of that which would be had if the exact preferred angle had been used.

This antenna No. 2 was tuned and adjusted by means of [fol. 203] the U-shaped loop, extending from MN to the antenna point CD, that loop being of the sort shown in Figs. 2-C, 5 and 11, of the third Carter patent. It is formed of the cross connection MN and the parallel wires KIC and LJD extending from MN.

Thus the antenna utilizes the arrangement that is explained at page 2, lines 114 and following of the third Carter patent.

I have already pointed out in connection with the Lindenblad patents that the two wires of the V are excited in phase opposition through the transmission line, which is also true of the antenna of the third Carter patent; and also that the wires have open ends so that standing waves are developed along their lengths; and that the standing waves have opposite polarity at corresponding points along the two wires at any particular instant.

In all of these things, the antenna No. 2 corresponds to the disclosure of the third Carter patent.

Q. 93. Now, Mr. Hogan, referring to this description and the model, if they will help you in any way, will you please describe generally the system of antenna No. 8?

A. On the map, which I think was Exhibit 23A, the No. 8 antenna is shown by the double V at the southwest corner of the property. It is illustrated as to its construction diagrammatically in the drawing attached to Exhibit 7 and it is described in considerable detail in the text of the tabu-

lation, the text of Exhibit 7 and the tabulation of Exhibit 13. It is also represented by the scale model, Exhibit 29. The antenna system comprises two V's both located in the [fol. 204] same horizontal plane 80 feet above the ground approximately and with their corresponding side wires parallel to each other.

The included angle of each of the two sections is, as shown on the diagram, 45 degrees. Both sections are supplied with radio frequency power at the operating frequency of 5990 kilocycles through a two-wire transmission line that extends from the transmitter a distance of about 800 feet to the points IJ which represent the junction point beneath the apex of the nearer antenna section. From that point the transmission line extends horizontally 123 feet further to a point below the apex of the second V and also extends upwards a distance of 42 feet from each of the points below the respective apices to the corresponding apex of each section.

The call letters used with the antenna were WMZ or WMZ-20 and the wave length is 50.08 meters, or 164.3 feet. The antenna was stated to be used for transmission to San Francisco and to Chicago. The great circle bearings of those two cities from Sayville are respectively north 281.28 degrees east and north 278.46 degrees east. The direction of the bisector of the two V's which is called the directivity of the antenna in the stipulated tabulation of Exhibit 13, when that is taken from the center of the V's toward their open ends, is north 281.95 degrees east. Consequently, the bisector bears almost exactly upon San Francisco and closely on Chicago.

Q. 94. Will you please compare the structure of antenna No. 8, Defendant's antenna No. 8, with the disclosure of the first Carter patent, particularly with reference to the first [fol. 205] objects stated therein at page 1, lines 24 to 31?

A. In this antenna No. 8 the transmission lines which deliver power from the power house or transmitting generator to the antennas or to the two antenna sections are 842 feet long to the points CD on the one section and 965 feet long to the points C'D' on the second section. The 800-foot portion from the transmitter to the points IJ is common to the transmission line to each of the two antenna sections.

The lines have uniform characteristics throughout their lengths, being made of the same No. 6 wire with 12-inch spacing to which I referred in connection with antenna No. 2. Thus they have a characteristic or surge impedance of approximately 600 ohms.

In this antenna system there are three points where there are electrical conditions of the sort that would set up substantial reflection of energy back toward the transmitter and therefore would produce standing waves in the line connecting to the transmitter unless impedance matching arrangements were provided.

The first of those points which would tend to set up reflection is the junction point IJ, where one transmission line divides into two sections of a transmission line. The other two points are at or near the antenna apices CD and C'D', where the change from the antenna into the transmission line has its effect.

Referring to this first Carter patent, I may point out that the arrangement of the No. 8 antenna corresponds generally to the showing of Fig. 3 in the patent. Thus the two Sayville antenna sections AC, BD, and A'C'B'D' correspond to antennas 31 and 34 in the patent drawing. The [fol. 206] transmission line 10' from 37' to 38' corresponds to the antenna No. 8 line from IJ to C'D' by way of I'J' supplying power to the right hand antenna in both pictures.

The shorter transmission line marked 10 in the patent drawing running from 37 to 38 corresponds to the shorter transmission line from IJ to CD, supplying power to the left hand antenna, section of the antenna system No. 8, and also the left hand antenna 31 in the patent drawing.

At Sayville there is a single source or transmitter indicated at the left of the chart of antenna No. 8, and power from it is supplied to both antenna lines and to both antenna sections over the long common transmission line from the transmitter to the power junction IJ.

In Fig. 3 the power junction is at this three-coil transformer having the coils 13, 37' and 37, and power from the transmitter in the patent drawing is supplied over the wires connecting to the coil 13.

With respect to the patent, in a case corresponding to the case of Sayville's antenna No. 8, if the power junction IJ, or, looking at the patent drawing, 13, 37 and 37', is at a considerable distance from the transmitter, it follows

from Carter's teachings that the long transmission line must feed into a matched load in order to obtain the desired high efficiency line substantially of electrically infinite length or substantially reflectionless.

At Sayville, there is a match between the surge impedance of the line, and the load which is presented at or close to the junction point IJ, and that match is provided by means of the line section, which extends from IJ to the [fol. 207] connections KL, and by the line shunt reactance provided by the wires KM and LN. In their effect, the line section and the reactance connected across the line are equivalent to the impedance matching transformer 13, 37, 37′ shown in Fig. 3 of the Carter patent, when that transformer is adjusted to match to the load of a long line from the generator to the coil 13.

The stipulated description states that in antenna No. 8 an approximate impedance match was provided at KL, and by reason of that energy was efficiently transformed across the points KL and reflection of waves towards the transmitter from those points was reduced. Thus there has been made at the time the antenna was installed and adjusted in antenna No. 8 the adjustment that is described by Carter in which the reflection on the long line back towards the transmitter from the junction point or the corresponding matching points is reduced or minimized so as to make that line substantially of electrically infinite length as we are using that phrase, or substantially reflectionless, and so to provide the desired high efficiency of the line.

I might point those elements out on the model, if your Honor would care to have me do so. The long line extends from the transmitter house to the first pole, and across that is connected at a point some distance back toward the transmitter, relatively a few feet, a pair of parallel wires which constitute a shunt reactance connected across the transmission line at the point before the junction is reached. Then the transmission line carries forward to the junction and goes in two directions, first, horizontally to the second [fol. 208] antenna section, and vertically to the first antenna section.

There are two other matching circuits, one at each of the antenna systems, to which I will refer later; the one which has to do with the prevention of reflection along the main line is the one below the junction point which I have already described.

Q. 95. Now, will you please compare defendant's antenna No. 8 with the disclosure of the first Carter patent, particularly with respect to the second object stated therein, at lines 31 to 36 of page 1?

A. Yes. In this connection we are interested particularly in the portion of Fig. 3 described in connection with matching the transformers 38, 32 and 38′, 35 of Fig. 3 of the patent. At page 2, beginning at line 10, it is pointed out that they are to be adjusted, so as to make the lines 10 and 10′ of electrically infinite length, that is to say the same adjustment is to be made at those coils as had been described in the earlier part of the patent, as to the coils in Figs. 1 and 2. That results in making the antenna load resistance in each case match the surge impedance on the associated transmission line.

Now, in the Sayville antenna No. 8, that same match is provided for each of the two antennas and the directly connected transmission lines associated with each of the antennas are matched in that same way by means of equivalent matching circuits EGHF for antenna ACBD and E′G′H′F′ for the antennas section A′C′B′D′.

It is set forth in the stipulated description in the same way that an approximate impedance match was provided at [fol. 209] each of the pairs of the points E′F′ and EF, and also the description sets forth the result that energy is efficiently transferred across each of those pairs of points and reflection of waves towards the transmitter from each of those pairs of points is reduced.

The object of the impedance matching directly below each antenna section in antenna No. 8, or in any other multiple radiator directive antenna system of the same type, is in accordance with that of the second object of Carter's specification, the second object of Carter's invention, which is stated at page 1, lines 31 and following of the specification.

I have explained in connection with the patent when you use transmission lines of electrically infinite length, even though the physical length may be relatively short, it is possible to fix and maintain the proper relations of the phase and intensity of the currents in the several antenna sections in the way Carter pointed out on page 2 of the specification, beginning at line 40.

In Fig. 3 and Fig. 4 of Carter's first patent, the spacing between the antennas is only a quarter of a wave length,

and at Sayville the spacing between the two antenna sections is only 123 feet, or three-quarters of a wave length.

When you have such short transmission line sections as those between the two antennas in Fig. 4, for example, or the three-quarter wave length section between the two antennas, in the antenna No. 8, the increase of transmission line efficiency in that part of the line that results from the matching is not of great importance. It is much less important, for example, than the provision of the simple and effective way of fixing the relative phase and excitation of [fol. 210] the two antenna sections in accordance with Carter's second object.

Of course, insofar as the current in those lines is reduced and therefore radiation from them is minimized, and thus prevented from having any effect, or having as great an effect upon the radiation pattern of the antenna, it is useful from the mere point of efficiency, but the most important thing is the control of the phase and amplitude relations.

I might point out those two loops briefly in connection with the model. Here, instead of having a pair of open wires connected across the transmission line, there is a closed loop directly below the apex of the antenna. Similarly on the other antenna section a closed loop is connected directly across the transmission line directly below the apex. That provides the match where the loop is connected across in connection with the vertical section, and therefore prevents standing waves on the transmission line section between the two antennas, which allows one to fix the phase and amplitude relations in a system in a way that could not be done otherwise.

I might summarize with respect to this first Carter patent and antenna No. 8 by pointing out that both, as shown in Fig. 3 and antenna No. 8, have their antenna sections spaced by an odd number of quarter wave lengths, that they are supplied with equal radio frequency power in such relative phase as to be unidirectional; that in each case, the single transmitting generator is connected to the two antennas by means of a two-wire transmission line, substantially of an electrically infinite length; and with respect to the first [fol. 211] object that the impedance match at the power junction provides a high efficiency long line and makes possible the use of antennas erected at a considerable distance from the transmitter house; and with respect to the second object, that the impedance match in the antenna connection

itself permits use of the transmission line length to determine the phase difference and to maintain that as between the two antenna sections, and also to determine and maintain the relative current values. In that way, the No. 8 antenna also embodies the specific features that I have described in connection with the first Carter patent and attains the objects that he sets forth.

Q. 96. Have you prepared a diagram of the impedance matching system of this antenna No. 8?

A. Yes.

Q. 97. Will you explain, please, how the impedances are matched in this antenna system at the junction point IJ, or rather at KL, and compare that matching circuit with the second Carter patent in suit?

Mr. Blackmar: At this point, I offer in evidence the diagram of the impedance matching system of antenna No. 8 referred to by the witness.

(Marked Plaintiff's Exhibit 31 in evidence.)

A. This Exhibit 31 is generally an expanded layout of the impedance matching system, for antenna No. 8, following the same general conventions as those which I used for antenna No. 2, in order to show the matching arrangement [fol. 212] in greater detail than could be done in the drawing attached to Exhibit No. 7, the stipulated description.

There are three impedance matches in this system of antenna No. 8, and all of them are attained by means of the specific type of matching circuit that is described in the second Carter patent 1,909,610. The first match is the one as to which this question was directed, and is the one shown at the lower part of Exhibit 31, where the line from the points IJ to the transmitter is shown extending off to the left. The distance of 12 feet between IJ and KL is subtracted from the total distance of 800 feet to the transformer, giving a balance of 788 feet from the points KL to the transformer.

The transmission line has a surge impedance of 600 ohms, and the load at IJ is made up of two similar transmission lines, connected in parallel to that same point. Therefore the resistance of the two lines together, the joint effect is of the general order of one-half that of one line, and therefore of approximately 300 ohms.

That, of course, gives at IJ a load resistance which is less than the surge impedance of the line back toward the transmitter.

There is a shunt reactance marked "Capacitive Reactance" in Exhibit 31, provided by the two 15-foot wires KM and LN, and that reactance is connected to be effective at the point KL, as I have said, 12 feet back towards the transformer from IJ.

Now, the first quarter wave section from IJ back toward the transmitter extends 41 feet. Consequently the connections KL are within that first quarter wave section shown in [fol. 213] Exhibit 31, and being a capacity or capacitive reactance across the line and connected in the first quarter wave section, are of the character to use where the load resistance is less than the surge resistance of the line, and therefore correspond to case No. 1 of the tabulation on page 2 of the Carter patent as is described at page 1, lines 28 and following, and page 2, lines 18 and following, and as is illustrated by Fig. 2 of the patent.

Q. 98. Referring to the chart, will you explain what the figures are above the words, "Impedance Matched at KL", and what they indicate?

A. The figures immediately above "Impedance Matched at KL", on the chart are the Greek letter lambda stroke 4, and that is a shorthand way of saying one-quarter wave length. In other words, the wave length divided by 4. The distance represented by the arrows on each side of this symbol indicates the extent of the quarter wave length section, although, of course, this diagram is not drawn to scale, but it is relatively correct.

Referring to this Fig. 2 of the patent, the source of alternating current energy 2 in the drawing corresponds to the transmitter of antenna No. 8. And the line marked 6, in the patent drawing, corresponds to the main line or 800 foot transmission line with its surge impedance of about 600 ohms.

The capacitive reactance 10 which is required for case 1 of the Carter patent is provided in antenna No. 8 by the capacity between those two open ended wires KM and LN to which I have referred. Each of those wires acts as one of the plates of a condenser, the effective value of the capacity [fol. 214] reactance being determined by the size, that is to say, by the length of those wires in this case. The load

marked 4 in Fig. 2 of the patent is represented by the resistance at IJ, the junction point, and that being of the order of 300 ohms, it is less than the surge impedance of 600 ohms, and that corresponds with the statement at page 1, lines 81 to 85 of the patent.

In Fig. 2 of the patent, the distance between the load and the cross connected reactance is stated as not over one-quarter wave length. Reference to Exhibit 31 shows that with the load at IJ and the reactance effectively connected at the points KL the distance between them is not over a quarter wave length.

Therefore we have a situation in which the value of the load, the length of the line section between IJ and KL and the value of the capacitive reactance effective at KL combine to produce an impedance match at the points KL, just as explained in the Carter patent. This depends upon the length and position of the wires, bearing in mind that the length KM-LN determines the amount of the shunt capacity reactance and the length of the line section is determined by the point of connection. Those two things were adjusted when the antenna system was installed to provide efficient transfer of energy across the points KL and thus to reduce the reflection of waves toward the transmitter, as is stated in the stipulated description of antenna No. 8.

That describes the condition of a practical match between the surge impedance of the line and the resistance of the load which results in the desired high efficiency long line.

[fol. 215] I pointed out that the length of the line from the matching points KL to the transmitter was about 788 feet, but I did not point out that that was equal to about four and three-quarter wave lengths.

Q. 99. Will you please compare the other two matching circuits, namely, those at the antennas, in connection with this antenna system No. 8, with this second Carter patent?

A. Yes, the two matches on the transmission lines just below the antennas are indicated by the central and upper figures in Exhibit No. 31. In each of those there is a pair of points marked IJ, which is to be understood as being connected to the points IJ, on the bottom part of the diagram, and so providing the connection through from the transmitter source to each of the two antenna sections.

Taking up the second impedance match in antenna No. 8 as between the vertical transmission line section running

upward from IJ and the load provided by the antenna ACBD at or near the points CD, I would refer to the upper diagram in Exhibit 31. This match is quite similar to that which I have already explained in connection with antenna No. 2. The situation is very much the same except that in antenna No. 8 the resistive load of the antenna is greater than the surge impedance of the line because points C and D are almost exactly an even number of quarter wave lengths from the open antenna ends A and B and that, as I pointed out, results in a high terminal impedance rather than a low value.

The shunting inductive reactance provided by the half turn loop EGFH is connected 27 feet from CD, that is to [fol. 216] say, in the first quarter wave section, since a quarter wave is about 41 feet, and thus the arrangement corresponds to that of case 2 of the Carter second patent.

The third impedance match in antenna No. 8 is in the vertical below the apex C′D′ and it corresponds to that which I have described in connection with the outer V antenna section. The only difference between the two is a slight variation in the individual dimensions such as would be expected under practical conditions.

The stipulated description sets forth that EGHF and E′G′H′F′ were adjusted to provide an approximate impedance match at EF and E′F′ so as to permit efficient transfer of energy across those points and to reduce the reflection of waves toward the transmitter.

That is the condition that results in obtaining Carter's objects including the stable control, by the length of the transmission line, of the relative phase and current amplitudes in the two antennas, and is an important consideration in connection with obtaining the best directive radiation from a double antenna system of this kind.

Q. 100. In connection with the three impedance matching circuits of this antenna system No. 8, is there in any case anything besides the load, that portion of the line between the load and the shunt reactance and the shunt reactance, that enters into the impedance matching circuit?

A. No, there is none. The match is attained by the cooperation between the load, the section of transmission line between the load and the matching point, and the shunt or effective reactance connected across the matching points.

Q. 101. And only by those elements?
A. That is correct.

[fol. 217] Q. 102. In either case is there any serially connected impedance in the line between the source and the load?

A. No, the line is uninterrupted from the source to the load.

Q. 103. Will you please describe other details of the system of defendant's antenna No. 8?

A. Looking at either section of antenna No. 8, which is a double V antenna, it is clear that it is substantially identical with the single V antenna No. 2 that I have already discussed, except, of course, as to the matter of dimensions. The No. 8 antenna also has features that I have described in connection with the No. 2 antenna. It also has some of the additional features not present when only one pair of wires is used.

Summarizing briefly, the radiating wires are each four wave lengths long, the antenna is directive, the wires of each of two pairs are supplied with power in phase opposition, and all the antenna wires carry standing waves. The standing waves of each pair of wires are of opposite instantaneous polarity. All of the wires have open ends. That provides reflection points and favors the development of standing waves in the radiating parts of the system. And the principal radiation is along the line that bisects the included angles of the two V's.

Like antenna No. 2, also, the radiation is concentrated generally in the plane of the wires, and the wires of each of the two sections of the antenna are arranged so as to diminish one pair of lobes and thus to augment the other pair. That provides, for each unit, bi-directive radiation.

Antenna No. 8, however, brings in another feature of the [fol. 218] first Lindenblad patent, namely, that which is described in the specification beginning at line 43 of page 3. That is the provision of a second pair of wires similar to the first pair, and each one having its corresponding wire parallel to that of the other pair.

Those two pairs are arranged at a distance of an odd number of quarter wave lengths in the direction of wave radiation, and they are excited with the relative phase difference that will cancel one-half of the bi-directive radiation from

the single pair. That not merely cancels one of the lobes, but reinforces the other one and so gives increased unidirective radiation. In the case of antenna No. 8, that unidirective radiation is projected almost exactly in the plane containing a great circle bearing toward San Francisco.

Q. 104. Will you please briefly compare the system of defendant's antenna No. 8 with the disclosure of the second Lindenblad patent in suit?

A. Referring again to Fig. 2 of the second Lindenblad patent, 1,927,522, I would only point out that this No. 8 antenna, like the No. 2 original form of antenna which I have already described, embodies the features disclosed in the second Lindenblad patent with relation to Fig. 2. One may consider either the section ACBD or the other section with the prime letters. There are two long open-ended wires which are excited in phase opposition. The two wires of each pair diverge as they are extended from the apex, from CD or C'D' in the general direction of principal radiation. The axis of the antenna system lies in that direction of principal radiation and the destination points, stated as San Francisco and Chicago, lie quite closely along that axis.

[fol. 219] Q. 105. Will you please compare defendant's antenna No. 8 with the disclosure of the third Carter patent in suit, Plaintiff's Exhibit 5?

A. The explanation that I gave in connection with antenna No. 2 applies generally with respect to antenna No. 8, since antenna No. 8 is made up of two single V sections. Of course, the preferred angle for No. 8 is different because the wave length used is different and the length of the side wires of each of the V's is different from that in antenna No. 2. However, for antenna No. 8, where we have side wires that are an even number of half waves long, the preferred angle may be determined either from the formula at page 2, line 70 of the specification, or from the general formula covering all lengths at page 2, line 85. The wave length used with antenna No. 8 is 164.3 feet, and each side wire is 657 feet long. Thus, the length of each wire is almost exactly four wave lengths and either from the formulas or from the chart, Fig. 12 of the patent, the preferred angle between either wire and the bisector would be 25 degrees.

In the actual case of antenna No. 8, the angle from the wire to the bisector is half of the included angle of 45 degrees, or 22.5 degrees. That, of course, is 2.5 degrees

smaller than the preferred angle. For practical purposes, however, the angles are effectively the same. The angle used, that is to say, 22.5 degrees, causes the radiation from the system in the desired direction along the bisector to be 12.1 times as powerful as the radiation from a simple di-pole antenna would be with the same power.

If the preferred angle of 25 degrees had been used, the [fol. 220] power gain would only have been increased by a small amount, namely, to 12.6 instead of 12.1, and, consequently, with the angle used, antenna No. 8 has more than 96 per cent of the power gain that would be had if they were in perfect agreement with the preferred angle.

The two sections of antenna No. 8 are so arranged that their combined radiation is principally unidirective and in the direction of the bisector; as I have explained, and as the specification sets forth, particularly at page 1, lines 43 to 55, and then again in connection with Fig. 5 of the patent, at page 3, lines 60 to 88, antenna No. 8 corresponds quite closely to the showing of Fig. 5 of the patent, the principal difference being that in antenna No. 8 the lower wires which are not marked with reference characters in Fig. 5 are omitted. Those are the additional wires for causing additional concentration of the radiation with respect to the vertical plane, and I think I have pointed out that those were not used by defendant.

In Fig. 5 of the patent, as also in antenna No. 8, there is a supply of high frequency power from the transmitter by means of a transmission line. The line is marked 24, or the connections to it, in Fig. 5. There is in Fig. 5 a rectangle just to the left of the left hand pole, which indicates a device for matching impedance at the junction joint, and in the case of antenna No. 8 the match for that point is provided by the circuit including the IJ, KL and MN, which I have already described.

The impedance matching device of Fig. 5 is described at page 3, lines 148 and 150, with the reference numeral 40 in its similar application to Fig. 11, but is not marked with a reference numeral in Fig. 5 of the patent.

[fol. 221] In the arrangement of Fig. 5 a branch of the transmission line extends upward to the apex of the left hand V and another branch of line is provided to connect it to the apex of the right hand V. That same situation exists in the case of defendant's antenna No. 8.

In Fig. 5 both the antenna sections are tuned and matched to the lines by means of parallel wires and U loops from the apices to the short circuiting members 32 and 32′ in Fig. 5, and those correspond with the loops CD, EF, GH, and the same reference letters with primes, in the two sections of antenna No. 8.

Similarly, in Fig. 5 of the patent the V wires themselves are electrically open-ended, and in the defendant's antenna No. 8 the antenna wires are electrically open-ended or insulated. Insulators are shown, for example, at reference numerals 22 of the patent drawing, and by the open ends AB, A′B′ in the chart of Exhibit 7, showing defendant's antenna.

The unidirective radiation pattern of the antenna of Fig. 5, showing the power distribution in the horizontal plane, is given at Fig. 6 of the patent and described by reference at page 3, line 73 of the specification. That patent is also illustrative of the unidirectional radiation from an antenna of the kind represented by defendant's No. 8. The cancellation of backward radiation and the reinforcement of the desired forward radiation is produced both in the arrangement of Fig. 5 and in defendant's arrangement by spacing the two antenna sections by an odd number of quarter wave lengths measured along the bisector. That is referred to specifically at page 1, line 45 of the patent, and again at page 3, lines [fol. 222] 60 to 67. The patent states there that the distance may be, in the preferred arrangement, equal to an odd number of quarter wave lengths.

At page 4, lines 16 to 19, Carter points out that for wires of the order of three or four wave lengths long the reflector spacing from the antenna may be one and one-quarter wave lengths or less. In this case the wire length is four wave lengths and the spacing is the next odd multiple less than one and one-quarter wave lengths, that is to say, three-quarters of a wave length.

In the example of Fig. 5 of the patent that distance is given as nine quarter wave lengths, Carter having pointed out the desirability of increasing the number of quarter wave lengths so long as an odd number is used, as the length of the wire increases.

In addition to that matter of spacing, it is necessary to excite the two pairs of wires so that the currents in one pair have a phase difference of 90 degrees with respect to the currents in the other pair. And both in the case of the antenna of Fig. 5 of the patent and antenna No. 8 of the

defendant, that is done by means of matched horizontal transmission line section extending from one section to the other, that is, the length from IJ to I'J' in antenna No. 8, which is, as I have stated, an odd number of quarter wave lengths long.

Relative phasing of that kind with equal antenna currents in the two sections results in a practically complete cancellation of backward radiation and it is the preferred case for two antenna sections of the condition that is established by the little phase difference formula at page 3, line 125, as to which I was questioned this morning.

[fol. 223] The application of that formula is quite simple, in that it works out that if the spacing, S, is one-quarter wave length, the timing should be pi over 2, or 90 degrees, pi being equivalent to 180 degrees.

Q. 106. If the spacing is three quarters wave length, as it is in the case of defendant's antenna 8, what is the result of that formula?

A. The resultant comes out three pi over 2, or 270 degrees, which is the same as minus 90 degrees, that is, 90 degrees in the other direction. Therefore, the phase difference is still 90 degrees, since it takes no account of sign.

I have already pointed out as to this antenna No. 8 in connection with the Lindenblad patents that the two wires of each V are excited in phase opposition through the transmission lines. The V's have got open or insulated ends and in that way the development of standing waves along their lengths is favored. Because of the excitation in phase opposition, those standing waves have opposite polarity at corresponding points along the wires at any instant.

Because of the phase difference produced by the horizontal section of the transmission line extending from the point below one apex to the point below the other, the standing waves at corresponding points on the two corresponding and parallel side wires of the two V's that is, for example, AB and A'B', are 90 degrees out of phase at any particular instant.

That summarizes the similarity in the features of the antenna described in the patent and of No. 8 of the defendant represented by the model and shown in the drawing attached to Exhibit No. 7.

Q. 107. Going back to the first Carter patent in suit, Plaintiff's Exhibit 3, will you very briefly compare its dis-

[fol. 224] closure with the other single V antennas at Sayville where there is any difference between them and No. 2 already covered?

A. In connection with this first Carter patent, I have described single V antenna No. 2 in its original form. The other single V antennas at Sayville are No. 2, as it was rebuilt, No. 3 in its original form, that is, as it was when the suit was filed, No. 3 as it was rebulit, and No. 11.

Now, Nos. 2 and 3 in both their original and their rebuilt forms are illustrated by the drawing of the WML antenna system which was part of Exhibit No. 10, that being modified, of course, by the dimensional differences and any other data given as to each in the tabulation of Exhibit 13, the column arrangement to which I referred this morning.

The only structural difference between those three antennas is that the matching circuit reactance KMNL in the rebuilt antenna No. 2 was open instead of having a cross connection; changing, therefore, from an inductance to a capacity reactance.

Antenna No. 11 is a little different, however.

Q. 108. Have you prepared a chart of the impedance matching system of antenna system No. 11?

A. Yes, and in connection with that I would like to refer to the drawing of antenna No. 11 which is annexed to Plaintiff's Exhibit 11.

Mr. Blackmar: I will offer in evidence the chart of the impedance matching system of antenna system No. 11 to which the witness has just referred.

(Marked Plaintiff's Exhibit 32 in evidence.)

[fol. 225] A. (Continuing.) In this antenna No. 11, illustrated in Exhibit No. 11, the resistance of the antenna is matched to the surge impedance of the transmission line by means of a matching transformer that is made up of two adjustably spaced parallel copper tubes marked EG and FH instead of by the matching circuit shown in Exhibit D.

These tubes, your Honor, are located vertically just below the apices of the antenna and form part of the transmission line connection from the transmitter to the antenna.

It has been shown quite recently, comparatively recently, that copper tubes of that sort, if they are one-quarter of a wave length long and if they are properly adjusted as to

their spacing and diameter and their location, may be used as an impedance transformer for impedance matching.

So far as securing the desired matching of the line and the load impedance is concerned, their use is equivalent to the transformer type of circuit shown in the first Carter patent. Those two copper tubes, the vertical copper tubes, and their connections, provide a combined transmission line and impedance matching transformer.

The detail diagram of Exhibit 32 shows this system of antenna No. 11 leading out along a straight line across the paper.

It also shows that the load resistance corresponding to an odd number of quarter wave lengths for the wire and being less than that of the surge impedance of the line, the tube spacing and adjustment of length works out to give a substantial match. That is covered by the descriptions attached to the stipulation stating that in all of the antennas an approximate impedance match was provided by the ad- [fol. 226] justments made when each antenna system was installed.

The same statement is made as to all the antennas further that that resulted in an efficient transfer of energy across the matching points which here are the points GH at the lower ends of the tubes; and resulted also in reduction of reflection of waves toward the transmitter.

The explanation I have given for antenna No. 2 in its original form therefore applies insofar as the first Carter patent is concerned, to each of the other antennas, No. 2 rebuilt, No. 3 original, No. 3 rebuilt, and No. 11. In each case there either was, if they have been replaced, or is, if they are still in use, a practical match between the antenna resistance and surge impedance of the transmission line, so that each transmission line was made substantially of electrically infinite length, or substantially reflectionless, or having the desired high transmission line efficiency so that the power losses on the long lines would be reduced.

Now, the lines in these several antennas vary very considerably in their length, all the way from the shortest case, which was only a little over 100 feet, corresponding to nearly two wave lengths, right up to the longest case, where the transmission line was over 1100 feet long, or more than 12 wave lengths in length. No. 11 was the short one and No. 3 rebuilt was the longest one.

Q. 110. Now, will you briefly refer to the other double V antennas, and compare them insofar as they may differ from antenna No. 8 with the first Carter patent in suit?

A. The other double V antennas are Nos. 4, 5, 6 and 10, which are illustrated, except as to their dimensions, by Ex- [fol. 227] hibit 8, showing antenna No. 10; also antennas Nos. 1 and 9, which are illustrated, except as to dimensions, by the sketch showing antenna No. 1 in Exhibit 9. And finally No. 7, which is illustrated in Exhibit 12.

Then beyond what is shown in these diagrams there are additional data and specific dimensions given in Plaintiff's Exhibit 13, the tabulation.

Now, referring to Nos. 4, 5, 6 and 10, altogether, and really taking with them antennas Nos. 1 and 9, those are shown by the sketches of Plaintiff's Exhibits 8 and 9. They are all alike with regard to the disclosure of the first Carter patent. They are illustrated in two groups, because those of Exhibit 8 are connected and adjusted so that they radiate principally along the direction of the bisector from the center of the system, toward the open ends of the wires, whereas those in Exhibit 9 are connected so that they will radiate principally from the center of the antenna toward the apices, that is to say, the 180 degree reversal of which we have spoken is used.

That difference in connection and adjustment is described by Carter in his third patent, at page 3, lines 101 and following, but that does not have to be considered in connection with the first Carter patent.

All six of these double V antennas are like antenna No. 8, except as to their frequencies, dimensions and so on, and as to the type of impedance matching device which is used between the junction points and the apices. The matching circuit used between the junction point and the transmitter, that is to say, with respect to the long main feeding line, is [fol. 228] the same in all of these cases, and in antenna No. 8, and therefore need not be described with respect to each antenna.

Similarly the match below the antenna apices in each of these double V antennas is similar to that used with the single V antenna No. 11. The stipulated descriptions cover with respect to these double V antennas, as they did with respect to the single V antennas, that an approximate impedance match is provided between the load at the junction point, which is what we are considering in connection

with the main line, and the surge impedance of the transmission line; and, as I have said before, such a practical match results in making the long transmission line from the transmitter substantially of electrically infinite length, or substantially reflectionless, and thus avoids the power losses and provides the high transmission line efficiency.

Now, the transmission lines from the junction point to each of the antennas, for instance, C'D' or CD in each of these additional double V antennas are made reflectionless or are of electrically infinite length, by that copper tube arrangement represented by the sections marked EGFH, and E'G'F'H'. I have pointed out that those tubes and their connections are equivalent insofar as producing the desired matching of line surge impedance and load resistance is concerned, and also in supplying power from the transmitter to the antenna loads, to the other type of matching, or to the type of matching that is shown in the first Carter patent.

In all six of these antennas, as in No. 8, the matching devices between the junction points marked IJ and the apices [fol. 229] of each of the antenna sections are effective to transform the resultant load resistance of each radiating section to the value of about 600 ohms that is necessary to match the transmission lines. By providing an effective load of that value for each of the branches of the transmission line, between the power junction IJ and the radiating sections, the currents in the two sections of each of the antenna systems are equalized, and, of course, as I have pointed out, the phase difference is fixed at the desired value of odd quarter wave lengths by the lower horizontal sections; or, in other words, the difference in length of the two transmission lines, connected respectively to each of the two apices, and in that way the second object of the Carter first patent is accomplished.

The only other antenna of the double V type is No. 7. That is like any of the other antennas, 4, 5, 6, or 10, except as to its dimensions, and also except that it omits a matching device in the line from the transmitter to the junction points.

In this antenna No. 7, the length of that part of the transmission line, namely, from the transmitter to the power junction, is only 151 feet, that is only 1.66 wave lengths, one and two-third wave lengths, and as Carter showed, the matching of so short a part of the line is not of great im-

portance. However, in that antenna, the copper tube impedance matching transformers are used in the connections from the apices down to the junctio. points, and in that way the currents in the two antenna sections are equalized, and the line between the two antennas is kept clear of standing waves, so that its length will fix the phase difference in the way Carter specifies, and thus attain the second object of Carter's first patent.

[fol. 230] Q. 114. Now, will you please compare the disclosure of the second Carter patent, Plaintiff's Exhibit 2, with the V type antennas at Sayville, other than Nos. 2 original, and No. 8, insofar as they may differ from those?

A. Yes, leaving out original No. 2 and No. 8, with respect to the other Sayville antennas, Nos. 7 and No. 11, do not have the type of matching circuit that is shown in the second Carter patent. Original No. 3, I understand, had this circuit, but it had dimensions and arrangements, some of which we do not know now, and consequently, I haven't enough data to compare them with the patent.

Mr. Blackmar: I may say in the tabulation of defendant's antennas, giving the dimensional data, there were certain of them which are as entered unknown, and I assume that is because the defendant itself did not know at the time the stipulation was drawn up what they had been.

A. (Continuing.) In the rebuilt form of antenna No. 3, the load resistance is greater than the characteristic impedance of the line, and a shunt inductive reactance is connected across an odd numbered quarter wave length section, which is equivalent to making the line section, length of line, between one and one and a quarter wave lengths, and corresponds to case 2 of Carter's tabulation.

In all of the other Sayville antennas than those I have now referred to, that is to say, in No. 1, No. 2 rebuilt, No. 4, No. 5, No. 6, No. 9, and No. 10, the load resistance concerned in this particular match is less than the character-[fol. 231] istic impedance of the line, and a shunt capacitive reactance is used and is either connected at less than one-quarter wave length from the load point as in antenna No. 10, or on the basis that Carter has pointed out is equivalent to that, across an odd-numbered quarter wave length section, which is what occurs in No. 1, and in No. 2 rebuilt, No. 4, No. 5, No. 6, and No. 9.

All of those arrangements correspond to case 1 of Carter's tabulation. The agreed description in connection with each of those antennas, states that the matching circuits to which I have referred have been so adjusted as to provide approximate impedance matching, permitting efficient transfer of energy across the matching points, and a reduction of reflection of waves toward the transmitter.

Q. 117. Mr. Hogan, in your testimony so far you have compared the antenna No. 2 in its original form, and antenna No. 8 of defendant's Sayville Station with the disclosure of the first Lindenblad patent. Will you please briefly compare the other antennas with the disclosure of that patent, insofar as they may differ from those already taken up?

A. The other single V antennas are No. 2 rebuilt, No. 3 original, No. 3 rebuilt, and No. 11. They are very much the same with respect to the use of long, straight wires supplied with energy in phase opposition, and the other elements which I have pointed out in antenna No. 2.

The other double V antennas are Nos. 1, 4, 5, 6, 7, 9, and 10; and those are generally described as to their structure by what I have said with regard to double V antenna No. 8, and also insofar as that applies to the description of the single V antenna, No. 2 original.

[fol. 232] The lengths of side wires in each of the 13 antennas at Sayville, that is to say, the 11 numbers and the two additional forms of numbers 2 and 3, are given in the tabulation, Exhibit 13. The shortest of those wires is in antenna No. 8, where the side wires are each four wave lengths long; and the longest side wire is in antenna No. 2 as rebuilt. In that case the side wires are 8.14 wave lengths long.

Q. 118. With respect to the disclosure of the second Lindenblad patent, do you find anything in the defendant's antennas, other than Nos. 2 and 8, which differs from them?

A. No, I think that with respect to ~~this patent~~, what I have said about antenna No. 2 original for the single V type and antenna No. 8 for the double V type applies to all the others, with, of course, the exception that the dimensions are different. The wire lengths of all of the antennas fall within the range of from five to ten wave lengths, which is suggested at page 2, line 121, of the Lin-

denblad specification, with the exception of the rebuilt antenna No. 3, where the wire length is 4.85 waves, and antenna No. 8 which, as I have already said, has side wires four wave lengths in length.

Q. 119. With respect to the third Carter patent in suit, Plaintiff's Exhibit 5, will you please compare the defendant's single V antennas, other than No. 2 original, with the disclosure of that patent, insofar as they may differ from No. 2 original?

A. All of the single V antennas are like No. 2 in that they have open ends; the wires are excited in phase opposition; the wires carry standing waves principally, and those standing waves are of opposite instantaneous polar-[fol. 233] ity; also in each case, the principal radiation is bi-directive, as typified by Fig. 3 of the patent, and in both directions along the bisector.

Antenna No. 2 as rebuilt has an angle between the wires and the bisector of 20 degrees. For the wave length and the wire length used in that antenna, the preferred angle is 17.33 degrees, according to the Carter rule. That difference of 2.67 degrees is not of practical consequence. It serves to reduce the power gain along the bisector as compared to the signal from equal power applied to a half wave dipole from the multiplier of 10.9 to the multiplier of 9.3, and thus the antenna has about 90 per cent. of the maximum power gain for a structure of its size and general arrangement.

Antenna No. 3 in its original form had an angle to the bisector of 17.86 degrees. The preferred angle for the wave length and wire lengths used in that antenna is practically the same, that is to say, 17.88 degrees, and consequently there was very little if any departure from the maximum power gain of 9.8 times.

Antenna No. 3 as rebuilt has an angle of 21.5 degrees. The preferred angle would be 22.65 degrees, or 1.15 degrees greater. The loss in power multiplication by reason of that departure is only from about 7.1 to about 7, so again the antenna has about 98 per cent of the maximum power gain.

Antenna No. 11 has an angle of 17.5 degrees, and the preferred angle would be 17.88 degrees. That departure of .38 degrees reduces the power gain from 9.8 to about 9.7, and therefore the antenna has about 99 per cent. of

[fol. 234] the maximum power along the bisector again for its size and wave length.

No. 3 antenna as rebuilt is tuned and matched by means of a U loop which comprises the wires from CD, the apex, extending parallel and generally downward by way of the point IJ below the apex and the connection point KL to the cross connection MN.

Q. 120. Will you similarly consider defendant's double V antennas other than No. 8 with respect to the disclosures of the third Carter patent?

A. There are seven double V antennas in addition to No. 8, and they are all like No. 8, in the general items, that is to say, each system comprises two pairs of long open-ended wires; each of the pairs is arranged in the V formation and in all cases both pairs are located in the same horizontal plane with the corresponding wires of the two pairs parallel to each other; also, the two wires in each V are excited through a transmission line in phase opposition and they carry standing waves which are therefore of opposite instantaneous polarity.

Also in each case the length of the horizontal section of the transmission line from the point below one apex to the point below the other apex is an odd number of quarter wave lengths long and in accordance with Carter's disclosure the same number of quarter wave lengths as the spacing of the two antenna sections along the bisector.

That relation results in the condition which gives principal radiation unidirectionally along the bisector either toward the open ends of the V's from the center or towards the apices of the V's.

Antennas Nos. 4, 5, 6, 7, and 10 have their principal radiation toward the open ends, and antennas Nos. 1 and 9 [fol. 235] have their principal radiation toward the apices.

The reversibility of radiation is referred to in the specification at page 3, beginning at line 78, and running on down to line 104, and at the end of that section it is pointed out that by exciting one pair of wires in the opposite 90-degree relation, unidirectional propagation may be obtained in an opposite direction or toward the converging ends or apices of the antenna unit.

And in antennas 1, 5 and 7 the angle between the wires and the bisector is 20 degrees. The preferred angle, according to Carter's rule, is from 19.88 degrees to 19.93 degrees, depending upon the individual wire lengths and wave lengths used, so that it is only about one-tenth of a degree smaller than the actual angle. Thus, the power gain in each case is from 99 per cent. to 100 per cent. of the maximum for the preferred angle, which would amount to 17.2 or thereabouts. That larger gain is due, as I have pointed out, to the additive effect of the two antenna units.

Antennas Nos. 4, 6 and 9 each have an angle to the bisector of 17½ degrees. That is only about one-third of a degree less than the preferred angle for each case. Those preferred angles vary from 17.86 to 17.9. The power gain in each case is about 99 per cent. or more of the maximum attainable for those structures and wave lengths and that maximum is about 19.8 times.

Antenna No. 10 also has an angle of 17½ degrees, and that is about one degree less than the preferred angle for the wire length and the wave length used, namely, 18.53 degrees. That departure causes less than one per cent. reduction in the maximum power gain of 18.8, and there- [fol. 236] fore the agreement again is very good as compared to the radiation of maximum power.

Cross-examination.

By Mr. Darby:

X Q. 121. In answer to Q. 65 [R. p. 171], you were stating there the advantages of the first Lindenblad patent, Mr. Hogan, and you gave as part of your statement of the fifth advantage, namely, "the simple long wire antenna of this character has a high radiation efficiency, and by that I mean that a large percentage of the power applied to the antenna is radiated in the form of waves." And you say further, "In an antenna of this sort the radiation efficiency of the order of 90 per cent. or more is customary, whereas in antennas like the Model A, the curtain type antenna, the complicated network of which we have spoken, an antenna efficiency of 50 per cent or thereabouts, is about all to be expected."

What do you mean by "antenna efficiency", did you mean the same thing as radiation efficiency or what?

A. Yes, I was thinking of the fact that in the Model A, for example, there are losses in the tuning coils and supports which reduces the radiation efficiency, and by that I am distinguishing from the directive efficiency, of course.

X Q. 122. You use the term "radiation efficiency" in the one instance and antenna efficiency in the second instance. I was wondering if you meant the same thing.

A. It probably would have been better in that case if I had said radiation efficiency in both cases. Antenna efficiency is perhaps too general to use there.

X Q. 123. So that you mean to state, as I understand your testimony now, that the radiation efficiency in one instance [fol. 237] is 90 per cent and in the other instance was 50 per cent?

A. Yes, that is rough figures.

X Q. 124. Will you turn to the third Carter patent, and particularly Fig. 11?

A. Yes, sir.

X Q. 125. Will you tell me what is the little box-shaped device in the Fig. 11 of the third Carter patent, that is marked 40?

A. That is an impedance matching device. I think it is described in the specification merely by name.

X Q. 126. I presume, referring to Fig. 5 of the third Carter patent, that the little square device to the left of the figure and connected across the line 24 is likewise intended to represent an impedance matching device?

A. That is my understanding of it. Reference in the specification, as to Fig. 11, occurs at page 3 in the last three lines: "Energy is fed to the system through an impedance matching device 40."

* * * * * * *

X Q. 299. Now, I would like to refer you to the two figures 3 and 4 of the first Carter patent, as well as to Fig. 1 of the first Lindenblad patent 1,884,006. Will you tell me generally what is the difference between Fig. 1 of the Lindenblad patent and Fig. 5 of the first Carter patent?

A. Fig. 1, you asked for the difference, not the similarity?

X Q. 300. Well, either. Give me both.

A. All right. They are similar in that they are both plots or graphs indicating the distribution of radiation

around an antenna system. They are different in that Fig. 1 shows the characteristic cross section of a doughnut which represents the radiation around the half wave di-pole rep- [fol. 238] resented by the wire 2 in the center of Lindenblad's Fig. 1, whereas Fig. 5 of the Carter patent represents the horizontal directive characteristic of a pair of antennas with quarter wave spacing, as I have explained in connection with Figs. 3, 4 and 5.

X Q. 301. Does Carter 1 show a half wave di-pole structure?

A. Carter?

X Q. 302. Patent No. 1,263,996, does that illustrate a di-pole antenna system?

A. No, it represents a horizontal pattern that could be had with two vertical di-poles separated a quarter of a wave length, and excited in quarter phase relation, but it is not limited to that, or stated to be that.

X Q. 303. But what is illustrated, is the antenna radiator 2, for example, is that a di-pole, is that similar to a di-pole?

A. No, no, except in the general sense that they are both radiators, and so on.

X Q. 304. Now, I understood you to say that it was known even prior to this Carter patent that if you wanted to eliminate the rear lobe, and make an antenna unidirectional, you would place a second antenna spaced and phased for example in quadrature, and you would obtain that unidirectional effect, is that correct?

A. Very broadly, I think that is correct, yes; that is, that the cancellation in the rearward direction produced by the arrangement of two vertical antennas, for example, the quarter wave separation, and excited in quadrature, as you expressed it, did exist and was known prior to the application for this patent.

X Q. 305. So that that feature was not novel with Carter [fol. 239] in his Figs. 3 and 4 at the time of his application?

A. I think that is correct.

X Q. 307. Fig. 1 of the Carter patent does produce a pattern similar to Fig. 1 of the first Lindenblad patent, in that it is not unidirectional?

A. Well, the pattern of Fig. 1 would be substantially circular, and that is similar to Fig. 1 of the Lindenblad patent in that it is not unidirectional, but it really is very different

because Fig. 1 of Lindenblad is bi-directional, or in the vertical plane, non-directional.

* * * * * * *

X Q. 337. Incidentally, Mr. Carter, the patentee has been in the court room right from the beginning of the trial, has he not?

A. I think so; he may have been out part of the time, but he was in here when we started, and he is here now.

X Q. 338. He is that distinguished looking gentleman sitting at counsel's table?

A. He is sitting at counsel's table, and I think he looks distinguished.

X Q. 339. What are the limits by which you distinguish between a long wave and a short wave?

A. There are no specific limits; the terms are relative. The practice of the art is to put a convenient dividing line at about 150 meters, and say that waves longer than that are medium or long waves, and waves shorter than 150 meters but longer than 10 meters are short waves, and those shorter than 10 meters are sometimes called ultra short waves.

X Q. 340. In other words, they have the same difficulty with proper definition as between high and low voltage or current?

A. Yes, it is better if you want anything more than the [fol. 240] relative consideration to say what frequency or what wave length you are talking about.

* * * * * * *

X Q. 347. That reminds me, you were at the defendant's Sayville station, weren't you, at the same time Mr. Halsell was there, pursuant to our invitation to come out and inspect the equipment?

A. Yes, I was one of the party.

* * * * * * *

X Q. 355. Is Fig. 1 of the first Carter patent, No. 1,623,996, operative for short-wave transmission, in your opinion?

A. Yes, where the antenna is a short wave antenna.

X Q. 356. And just with the arrangement as shown in Fig. 1, what percentage of the reflected waves would be eliminated in your opinion?

A. That would depend upon the exactness of the match.

X Q. 357. What match, the match at coils 2-11?

A. 11-2, yes. You can get the standing wave down to the point where you cannot measure it with ordinary instruments.

X Q. 358. But if you were able to obtain a perfect match between the load 2 and the terminal 11, of the transmission line, it would be operative?

A. Not to the terminal 11, but to the surge impedance of the transmission line, if the antenna were a short-wave antenna.

X Q. 359. In other words, if the antenna was a short-wave antenna, and you could match the load coil 2 to the surge impedance of the line 10, it would be operative just the same as shown?

A. Yes. Of course, all the details of the system are not there. I mean, this does not pretend to show the details [fol. 241] of the source, but I see nothing in the teachings that would make it inoperative.

X Q. 361. You say it does not show the details of the source. It shows a source of current?

A. That is right.

X Q. 543. Now, will you please turn to the first Lindenblad patent No. 1,884,006, and, as understood you to testify with reference thereto, Fig. 2 of this patent merely illustrates the conical form of lobe that a wire, single-wire antenna will radiate?

A. It illustrates the largest lobe that will be radiated by a single long wire.

X Q. 544. A single long wire such as had been used prior to the date of the patent?

A. I do not know that they had been used in practice. In any event it represents what such a single long wire would do.

X Q. 545. And in Fig. 3, by using a pair of wires, the pattern of the larger lobe has been altered so as to concentrate the lobes into the form illustrated in the figure, and substantially cut off all waves above and below the plane of the wires, that is, above and below the plane of the paper, is that correct?

A. I wouldn't say it cut them off, but I would say it reduced them so that the principal radiation was in the plane of the wires.

X Q. 556. Now, the wires 14 and 16 of Fig. 3 of the first

Lindenblad patent are, as you pointed out, open ended, and they have standing waves on them?

A. That is right.

X Q. 557. You stated with reference to these wires, that they were several wave lengths long, in your direct examination. Insofar as having standing waves on them is concerned, does it make any difference how long the wires are [fol. 242] as long as they are open ended—that is, within practical limits?

A. One could have a wire so long in reference to the wave length that all of the energy applied was used either in the losses in the wire or in radiation, in which case, none would get to the remote end for reflection.

X Q. 558. You said that a wire a wave length long, open ended, would have standing waves in them?

A. I think that is the general practical case.

X Q. 559. And at one wave length long and open ended, they would still have standing waves on them, wouldn't they?

A. Surely.

X Q. 560. And at half a wave length?

A. Yes, as a general rule.

X Q. 572. Now, at page 1, line 33 of this first Lindenblad patent, the statement is made: "Furthermore, there is no radiation at right angles to the wire because although each half wave length oscillator might tend to radiate in this direction, the successive half wave length radiators are opposed in phase, so that at a distance from the wire the average effect is zero." Is that a correct statement, Mr. Hogan?

A. No, it is not full—it is not entirely correct. My understanding is that if the wire is an even number of half waves long, it is correct. If the wire is an odd number of half waves long, the extra odd section produces some radiation. It is small, of course, compared with the other.

X Q. 573. And this statement: "However, there is radiation in a direction intermediate the normal and longitudinal directions, and with a single conductor, this radiation takes place in the form of hollow cones having common axes in [fol. 243] the wire." That, of course, is referring to Fig. 2 of the patent, isn't that right?

A. That is right, and refers to the principal radiation, that is, the largest lobe.

X Q. 574. Then, again, at page 2, line 93, the statement is made: "It will be seen from the figure that these lobes are in the form of hollow cones having their apices adjacent and located in the conductor. In actual practice it should be kept in mind that there will be a number of different cones of various lesser magnitudes, and lying in different directions, relative to the longitudinal axis of the antenna, but for the sake of simplicity only the principal radiation is indicated, and its direction is indicated by the angle Alpha." Is that a correct statement?

A. I think it is generally correct.

X Q. 575. And that statement is true, for all antennae, isn't it?

A. It is true for all long single wires.

X Q. 576. Now, reference has been made several times here to this angle Alpha and the angle of staggering and like wise to the angle at which the waves are propagated in the plane of the wires. Does the patent state how to obtain that angle Alpha, or to determine that angle Alpha?

A. You are using Alpha for both of these?

X Q. 577. They are both of the same value, aren't they?

A. Yes, that is correct, I just wanted to be sure that we understood each other. There is no statement as to how that would be determined. That would be a matter of experiment for a particular case.

X Q. 578. We were discussing this angle Alpha, Mr. Hogan, and looking at Fig. 4, for example, or any of the [fol. 244] other figures for that matter, where staggered wires are shown?

A. Yes.

X Q. 580. The wires are staggered with respect to each other at an angle which is designated by the Greek letter Alpha?

A. Yes.

X Q. 581. And apparently, it is the same angle which the direction of the radiation of the waves bears to the axes on the antenna wire. It is correct that it is always the same angle?

A. That is my understanding, yes.

X Q. 582. You have just told me that although the patent has for its object the concentration of these lobes, which is attained only by the staggering as the important factor in conjunction with the excitation and phase opposition that the patent does not tell you how to determine that angle,

and that you can obtain it only by experimentation, isn't that just what you said?

A. Not exactly.

X Q. 583. Didn't you just say that you could obtain it by experiment?

A. Yes.

X Q. 584. Well, if you have anything else to say about it, please say it now.

A. What I had in mind was that the patent did not give a numerical determination of the angle Alpha for a particular case, and that having been shown the structure involving the stagger, as you brought out in this last question, the angle of stagger would be determined by measuring the experimental angle of principal radiation from the wire under that particular condition.

X Q. 585. Doesn't the angle of stagger determine the angle of radiation?

A. No; that is determined by the relation of the wire length to the wave length.

[fol. 245] X Q. 587. So that if you had the angle of radiation, which is determined by the wire length and the wave length, you would then match that angle by the staggered relation of the antenna, is that true?

A. In a sense. My idea is that the patent shows you that those are the same. Therefore, if you set up one of your wires and ran around that with an indicating instrument, to a distance sufficient to show the direction of a principal radiation, you could then stagger your wires at that angle, as shown in the patent, and you would have the cancellation, which is the feature of Fig. 4. That, of course, is again subject to practical modifications in the field because none of those theories apply to practical cases in exact detail. There are always compensating adjustments to be made by measurement.

X Q. 588. In other words, you do not know of any well-known formula for calculating that angle Alpha, do you?

A. I know the Carter formula now.

X Q. 589. That is the only formula you know, that is Carter's formula of Carter patent No. 3?

A. Yes, I think so. There have been approaches to it, but they have never been applied in this way.

X Q. 591. And the first time you ever knew of that Carter formula was when you saw Carter No. 3, I suppose?

A. Yes, that is correct.

X Q. 592. Then, am I correct in understanding that the angle Alpha as used in this Lindenblad patent is exactly the same angle Alpha that is referred to in the Carter patent, the third Carter patent in suit?

A. It works out to be the same angle. How complete Lindenblad's idea of it was mathematically or physically, I do not know.

[fol. 246] X Q. 593. We can go to the next step in this Lindenblad patent, which is represented in Fig. 5. And the next step is to eliminate the rear lobe and make the bi-directional antenna of Fig. 4 unidirectional, as illustrated in Fig. 5; that is correct, isn't it?

A. Yes.

X Q. 594. And that is accomplished by duplicating the antenna of No. 4 and spacing it in space and phase quadrature, is that right?

A. Along the line of propagation, as the space quadrature.

X Q. 596. And that is just exactly what was done in Figs. 3 and 4 of the first Carter patent in suit, isn't it?

A. It is exactly what is done when stated in such general terms as you have used.

X Q. 597. I believe that you also said at the time in discussing the features of the first Carter patent, that that was old and well known in the art even at that time?

A. Yes, in its most general terms.

X Q. 599. So that the second pair of wires which are spaced behind the first pair in proper phase and space quadrature in the direction of desired radiation acts as a reflector, is that right?

A. Well, it is often called that. The two are both driven, in this case, that is, they are both excited from the generator, so that the phases are kept accurately with relation to each other and, strictly speaking, the rearward antenna perhaps should not be called a reflector; on the other hand it is done frequently in the terminology of the art.

X Q. 606. Now, I call your attention to Fig. 6 of this Lindenblad patent. One difference between the arrangement shown in Fig. 6, and the arrangement shown in Fig. 7, is that the wires which are used as reflectors are separately [fol. 247] excited in Fig. 7, where as they are parasitically excited in Fig. 6, is that correct?

A. That is correct.

X Q. 607. They are equivalents, in so far as the reflector action is concerned, aren't they?

A. Quite approximately, they are. There are differences, but in general the operation is much the same.

X Q. 613. You, of course, know from your study of this subject and examination of the defendant's apparatus that each antenna is designed and used only for a specific wave length, don't you?

A. I think that is correct; for best results some modification is required whenever any substantial change in wave length is made.

X Q. 624. Now, Mr. Hogan, will you please refer to the second Lindenblad patent No. 1,927,522. As I recall your direct testimony, you confined your description largely to Fig. 2 of this patent. Do you recall whether you gave any description of Fig. 1?

A. No, I think I referred only to Fig. 2.

X Q. 626. Now will you please describe what is shown in Fig. 1?

A. Fig. 1 is similar to Fig. 2, except that no impedance matching device is shown, and except that the divergent wires are curved instead of straight.

X Q. 627. What kind of waves are there in Fig. 1 as described in the patent?

A. I thought the general description applied to both 1 and 2, either traveling or standing waves, and as a refinement, that the standing waves might be reduced. That is at page 1, line 38 and following.

X Q. 628. You recall, of course, the possibility of there being standing waves as specifically mentioned with respect to Fig. 2, and he therefore describes the use of an impedance [fol. 248] matching device?

A. No, I do not understand that, Mr. Darby. I thought the general description at the beginning of the specification applied both to Figs. 1 and 2 and the presence of impedance matching device had nothing to do with the existence or non-existence of standing waves, but had to do with the question of whether the transmission line was long compared to the antenna.

X Q. 629. Now will you describe briefly Figs. 3, 4 and 5?

A. Briefly, Figs. 3 and 5 represent extensions of the diverging sections to a greater distance, so that the total antenna will be longer by adding to the diverging section, therefore, successive converging and diverging sections.

Fig. 3 shows that with curved wires, and Fig. 5 shows it with straight wires.

As I understand it, Lindenblad's thought in that connection was that where a very long antenna was desired it was uneconomical to keep on with the same pair of wires diverging, and therefore becoming far apart at a great distance from the apex. Consequently, he took advantage of the fact that he might bring them together again and start out. So that while he still required a large horizontal extension of ground to put the antenna on, he did not have to have so wide a strip of land.

X Q. 631. All of defendant's antennas here before the Court under charge of infringement employ standing waves on them as distinguished from the pure traveling wave type antenna?

A. They use standing waves. Of course, all antennas have a traveling wave component, but the defendant's antennas, like the plaintiff's, are standing wave antennas in the general sense.

[fol. 249] X Q. 632. As you have ably pointed out in connection with the consideration of the first two Carter patents, all of the defendant's antennae employ impedance matching devices, that is, all to which you have referred in this case?

A. Every antenna has an impedance matching device somewhere in the system.

X Q. 633. This patent we now have under consideration, beginning at line 3, says, "Short wave antennas suffer from the disadvantage of having to be rather critically tuned to the working frequency, and from the further disadvantage of necessitating the use of some kind of an impedance matching device between the antenna and the transmission line connecting the antenna with the radio equipment".

So far as that statement is concerned, defendant's antennae all continue to suffer, do they not?

A. From the necessity of having an impedance matching device?

X Q. 634. Yes.

A. Yes, if that is suffering.

X Q. 635. And they are all critically tuned, aren't they?

A. Well, that would—I cannot say, because it would involve a definition of critical. They all are tuned, in any event.

X Q. 636. But they are tuned to a specific wave length?

A. Yes.

X Q. 637. Isn't that critical tuning?

A. Critical here means, as I understand it, that the change is less bothersome, less fussy than it would be in connection with antennas like the Model A. With regard to the fact that they are tuned to give an optimum result on a single wave length, if that is the meaning of critical, then defendant's antennas are critically tuned. With respect to the other meaning, they are not.

[fol. 250] X Q. 638. Then the patent continues, line 9, "It is an object of my invention to provide an exceedingly simple form of short wave antenna which will operate over a considerable range of frequency,". That expression means exactly what you have defined it to mean in connection with the first Lindenblad patent, doesn't it, that he can use the antenna as erected?

A. Yes, I think I explained it sufficiently there, that is, that the extent of adjustment necessary is less than in the case of the prior antennas.

X Q. 639. You do not mean to imply he could use this same antenna without reconstructing part of it at least and for a different wave length?

A. That would only be true in the strict traveling wave case. Let me make one other reservation when you said "without reconstructing a part of it", I am assuming that you are not excluding the idea that the antenna itself does not have to be changed, but that only the tuning adjustment of a coil or loop or whatever is used would have to be tuned in order to change the wave length. In the old antennas, where the di-poles were used and the antennas had to be exactly a certain fraction of a wave length in length and apart, there the structure had to be tuned. We are not misunderstanding each other on that, are we?

X Q. 643. But in defendant's antenna, the V type of antenna that they have at Sayville, here under charge of infringement, either the single V or the double V's, if you please, if they were going to change their wave length appreciably, according to you, they would not have to tear down the antenna and rebuild it or change the spacing between them?

A. They would have to change the spacing of the double [fol. 251] V's, but with respect to the single V's, they would

only have to retune, although if the wave length was changed very greatly on a short wire form, there would be some loss of power gain. We understand that?

X Q. 645. But if they wanted to obtain maximum power gain, they would have to change the angle of the V, wouldn't they?

A. For absolute maximum, yes.

X Q. 646. And the only way they could do that would be to tear down the poles, tear down the wires, position the poles at a different place?

A. That is a way of doing it anyhow.

X Q. 647. Do you know of any other way of doing it?

A. Yes, a variable antenna, that is, the antenna could be supported on a conductor between pairs of poles and moved in that way.

X Q. 648. I presume that you have in mind putting the poles on a truck and carrying the truck out, is that the idea?

A. Not at all. What I mean is, if you wanted to use an antenna, a single V antenna, successively at two different wave lengths and you wanted to get the angle correct for either of those wave lengths without moving the poles, which was your first suggestion, all you would have to do would be to support the end of each wire between the poles on a traveling trolley arrangement so that the wire could be pulled back and forth. I have done that very thing experimentally.

X Q. 649. And in any double V antenna, you have to change the special relation between them?

A. Yes, that would be more difficult to get the best cancellation.

X Q. 650. You would have to tear down the antenna and erect it in the proper spacial relation and move to a new position?

[fol. 252] A. Well, in some way or other, you would have to get the odd number of quarter wave length spacing between the antennas, whether you tore it down or not.

X Q. 651. After the patent has pointed out:

"The object of this invention is to provide an exceedingly simple form of short wave antenna which will operate over a considerable range of frequencies," it goes on and states:

"A further object of my invention is to provide an antenna with which a transmission line may be coupled without the use of intermediate impedance matching devices."

Now, what kind of antenna is that?

A. That is an antenna of the pure traveling wave type, or one in which the length of wires is very great.

X Q. 652. So if you do not want to use an intermediate impedance matching device, you would have a pure traveling wave antenna. With that understanding, can you compare Figs. 1 and 2 of the patent, and tell me whether or not Fig. 1 by its absence of showing of an impedance matching device shows a traveling wave antenna as distinguished from a standing wave antenna?

A. No, because there is more to it than that. The point is whether any discontinuity, such as would occur at points 8 and 10 in Fig. 1 will cause reflection on the line, and whether or not the line is so long that you do not want that reflection because of a loss of efficiency in the transmission line that it involves. I think that is described at the bottom of the second column of page 1. It is not merely a question of whether there is reflection from the open ends of the antenna wires, but it is a question of whether there is reflection from [fol. 253] any point in the system that would increase the losses on the transmission line.

X Q. 655. And the patent then goes on:

"My antenna consists simply of a pair of conductors which at one end are spaced at the spacing of the transmission line, and are coupled thereto, and which gradually diverge to a much wider spacing at their other ends."

Having in mind the sentence that I read first immediately above that, does that accurately describe Fig. 1?

A. It describes both Figs. 1 and 2.

X Q. 656. But Fig. 2 has an impedance matching device in it, hasn't it?

A. Even so, there is nothing that requires the omission of that in this description which you have read me.

X Q. 657. I asked you in the light of the preceding sentence which I read to you, which he wants to eliminate impedance matching devices. After he tells you he wants to eliminate impedance matching devices, then he says:

"My antenna consists simply of" what I read to you.

Does that describe Fig. 1?

A. Yes, it describes Fig. 1.

X Q. 658. And the two sentences together do not describe Fig. 2?

A. The second one describes Fig. 2, but the first one, that is something in which there is no impedance matching device, does not describe Fig. 2.

X Q. 659. Then my simple question is the two sentences together do not describe Fig. 2?

A. I do not know how to answer that, because half of it does and half of it does not.

X Q. 660. All right. And he continues:

[fol. 254] "In effect, therefore, the antenna consists merely of a gradually diverging extension of the conductors of the transmission line, and, in one aspect, the invention resides in the discovery that radiation may be obtained from a transmission line by gradually increasing the spacing between the wires of the line."

Does that describe Figs. 1 and 2 or Fig. 1 alone?

A. That describes the antenna portion of either Fig. 1 or Fig. 2.

X Q. 661. You consider in Fig. 2 that the radiating wires 2 and 4 are a mere continuation of the transmission line, do you, as shown?

A. As shown there, and as stated "in effect, therefore", which simply means for purpose of description.

X Q. 662. All right. Then the statement is made that "the desired radiation takes place in the direction of the axis of the pair of conductors".

That is another way of stating that it takes place in the bisector of the angle of the conductors?

A. It would include that, but I think it is a general statement as to the direction.

X Q. 663. Is there any difference between the axis and the bisector of the angle between them?

A. Geometrically speaking, there is none, but he points out about sideways radiation and so forth, and the complete description is that of radiation which is not strictly concentrated, but is radiated in the general direction of the axis.

X Q. 664. What justification have you in the disclosure in the patent, Mr. Hogan, for your last statement?

A. The statement immediately following the part that you read, at line 33, I think it is.

[fol. 255] X Q. 665. That is,

"Reflection will cause a standing wave instead of a traveling wave, and result in radiation sideways from the antenna."

Is that it?

A. Yes.

X Q. 666. And then it continues:

"Despite this, the radiation in the direction of the antenna is still considerably greater than that obtainable from a simple doublet."

I think you described, in your direct examination, what is meant by a doublet?

A. I think so.

X Q. 667. And then it further states:

"However, as a refinement the harmonic radiation may be lessened by reducing the standing waves, and to so do is a further object of my invention. It is not feasible, in the case of a transmitting antenna, to avoid standing waves by closing the end of the antenna with a surge resistance, because of the excessive losses which would take place therein."

Then he says:

"To lessen the standing wave I reduce the reflected energy by radiating as much of the energy fed to the antenna as possible. To merely increase the dimensions of the antenna is not practicable, for to increase the length without increasing the spacing, that is, to decrease the angle of divergence, does not increase the radiation" and so forth.

[fol. 256] He goes on to explain that it would take much spacing?

A. That is what you were talking about in connection with figures 3 and 5.

X Q. 669. Then he says:

"To overcome this I employ a plurality of antennas or pairs of diverging conductors, arranged end to end, so as to radiate cumulatively."

Those are the figures 3 and 5?

A. That is my understanding. This part of his picture relates to that long narrow arrangement.

X Q. 670. In other words, he finds disadvantages in the arrangements of Figs. 1 and 2, and therefore suggests, as

a means of overcoming these disadvantages, the arrangements of Figs. 3 and 5. That is a correct statement, isn't it?

A. I think so, if you do not mean to exclude the fact that he also finds advantages in Figs. 1 and 2.

X Q. 671. I understand that is your opinion, with which I may tell you frankly we are not in accord. The defendant does not use, in any of its antennæ which you here charge infringe, anything like the arrangement shown in Figs. 3 and 5?

A. That is correct.

X Q. 672. Then at page 1, line 103, in effect, he says, that with the arrangement shown in Fig. 1, he does not have to employ an impedance matching device. That is a fair summation, isn't it?

A. No, I don't think it is.

X Q. 673. All right, let us go back to line 95:

"However, in actual practice I find that the refinement of an exponential curve is not essential, and that the con- [fol. 257] ductors 2 and 4 may be straight conductors strung between the points 8 and 12,"

such as are indicated in Fig. 2,

"No impedance matching device is necessary with this antenna,".

What is he there referring to, Fig. 1 or 2?

A. Both, I believe, it is in the general discussion of Figs. 1 and 2.

X Q. 674. And he would not need an impedance matching device with either Fig. 1 or Fig. 2?

A. As he points out below, if the transmission line is short, this may be neglected, but if the transmission line is long, and the antenna is relatively small, so that only a small portion of the energy is radiated, it may be desirable to employ an impedance matching device between the transmission line and the antenna.

X Q. 675. All right. Now, what does he mean by short, and what does he mean by long? Does he state in his patent?

A. He points out—no, he does not distinguish between shorter lengths and longer lengths of wires that he pro-

poses to use, except that he recommends, at page 2, line 120 and 121, that the length of each antenna section should be of the order of magnitude of five to ten waves long.

X Q. 676. But he there refers to antenna wire, doesn't he?

A. You asked me about the transmission line?

X Q. 677. Yes.

A. Well, that would go back to the general idea of the transmission line that I mentioned before.

X Q. 678. He says that no impedance matching device [fol. 258] would be necessary if you had a short transmission line, is that the idea?

A. Yes, because then you would not be worried about the power loss in it.

X Q. 679. Let me ask you: Do you consider the transmission lines employed by the defendants to be short or long in the terminology of this patent?

A. Well, as we have just said, Lindenblad does not specify the lengths of his transmission lines, so I was answering as to lengths of the antenna. I pointed out in connection with the defendant's lines, that they vary from something over one wave length in a case which is not matched to, I think, as much as twelve lengths, where they are matched. There is no hard and fast line between long and short. The question is, if your losses are sufficient to make it worth while, you would like to use impedance matching to reduce them.

X Q. 680. Now, the antenna shown in Fig. 2 of this Lindenblad patent is bidirectional?

A. If standing wave component exists. If it has purely traveling waves, it will be unidirectional.

X Q. 681. Unidirectional along the axis of the V or bisector of the angle?

A. I assume in your question, and in my answer I used, bidirectional and unidirectional as describing whether the radiation was principally in the general direction of either side of the center line. I did not intend to have it taken in respect to the concentration on the bisector as a line. The fact is, there is sideways radiation in these Lindenblad antennas, whether mainly in one direction or extending in both directions.

X Q. 682. Now, how long would the antenna have to be to be a traveling wave or unidirectional antenna?

[fol. 259] A. That would depend on the wave length used, the resistance of the wire for the wave length, and the amount of radiation. In general, it would be quite long. Lindenblad says that the antenna sections may be five wave lengths to ten wave lengths long, so in the case of the multiple section type, the total might be 30 wave lengths long. I think that would give a very substantial reduction on the standing wave.

X Q. 683. I call your attention to page 2, line 103, where, in describing Figs. 3 and 5, he says:

"Radiation will occur substantially in the direction of a line perpendicular to the bisector of the angle between these two conductors."

That is equivalent to saying that radiation will occur substantially in the direction of the axis or bisector of the angle, isn't it?

A. Yes. You are simply asking me whether this is the bisector line. I do not see anything which requires the limitation of "the direction" in the strict "direction of", but I take it in "the general direction of", that is.

X Q. 684. Now, reading from line 96, preceding that,

"Taken from another point of view, we can consider merely the upper half of Figures 3 and 5 as being in a vertical plane with its image in the ground;"

Will you please describe what is meant by this image in the ground?

A. That I understand to be a theoretical discussion based on the old idea that a wire above a perfectly conducting [fol. 260] sheet can be represented as to its effects in the space above that sheet, by a system in which a so-called image of the antenna is assumed to exist below the sheet. That, I think, is what this refers to. As a practical matter, in short waves, my understanding is, no such image can be had, so I do not agree with the application of that to the practical case here. I think it must be regarded only as a theoretical discussion from the short wave point of view.

X Q. 685. From the short wave point of view, as I understand it, it is your opinion that any representation of this theory of image reproduction in the earth is absolutely wrong?

A. You are putting it very strongly.

X Q. 686. I am, I intend to.

A. My feeling is that one may in general terms discuss the operation of an antenna structure and its image, so as to get an idea of the operation, so as to understand the device more completely. With respect to the attainment of that by short waves, which is what we are considering here, I believe that it is practically impossible, that is, impossible in practice—I don't mean only substantially impossible.

You can not have a simple, complete image over any ground or marsh or sea water which we have available to us for support of an antenna when the waves are short.

X Q. 687. Now we will take up the third Carter patent in suit, and I am concerned, for the moment, with the differences between this patent and the second Lindenblad patent we have just finished discussing, in so far as they are material to the issues of this case.

[fol. 261] The Third Carter Patent likewise shows a V antenna, that is correct?

A. Yes.

X Q. 688. And it likewise shows a reflector spacing and phase in quadrature, that is correct, isn't it?

A. You don't mean that is shown in the Lindenblad patent also, do you?

X Q. 689. No, that is shown in the first Lindenblad patent.

A. That is shown in the first Lindenblad, a parallel wire multiple antenna system, comprising two multiple wires, those pairs being spaced and excited in space and phase quadrature. In the Carter third patent, there are shown two V's, similarly placed and excited.

X Q. 691. Maybe we can make a short cut. The third Carter patent differs from the first Lindenblad patent, in that the third Carter patent uses a V antenna properly spaced and excited, whereas the first Lindenblad patent uses parallel wires properly spaced and excited; that is one point of difference between them?

A. One point of difference between them, yes.

X Q. 692. Is there any other point of difference between them?

A. Yes.

X Q. 693. What?

A. The disclosure of the angle between the wires for best operation, the showing of specific matching circuits, and so on. I would have to go through the whole patent to point out all the differences.

X Q. 694. That flows from the fact that the third Carter patent employs a V as distinguished from parallel wires; that is your first point of difference?

A. Well, all of these things go together. I would hesitate to say what flows from which.

X Q. 695. As I understand it, the difference between the third Carter patent, and the second Lindenblad patent is [fol. 262] that the third Carter patent gives you the proper angle between the legs of the V and employs a second V in proper space and phase excitation, is that correct?

A. That is correct, so far as it goes.

X Q. 696. Will you please refer to Fig. 2B of this third Carter patent? Does that represent features of the third Carter patent which differ from what is disclosed in the second Lindenblad patent?

A. Yes, when taken with the specification. The picture itself looks very much like the Fig. 2 of the Lindenblad patent, except for the omission of the impedance matching device.

X Q. 697. Well, in what respect does it differ?

A. As a picture, as I said, principally by showing the angle to the bisector.

X Q. 698. Figs. 2A, 2B and 2C are described on page 1, line 74, as indicating various forms of the fundamental unit of the present invention, and the only difference I understand from you between Fig. 2B of this patent and Fig. 1 or 2 of the Lindenblad patent 1,927,522, Lindenblad No. 2, is in the specific angle between the V?

A. That is the main difference.

X Q. 699. Is there any other difference?

A. Yes, as to Fig. 1, I was just about to say, Lindenblad's second patent, Fig. 1, shows curved wires which are not shown in these.

X Q. 700. And Fig. 2 of Lindenblad shows an impedance which is not shown in Fig. 2B?

A. Yes, we referred to the impedance matching device.

X Q. 701. But Fig. 2A and 2C do show impedance matching?

A. Fig. 2C shows it specifically; Fig. 2A shows a circuit which may be arranged so as to match impedance.

X Q. 702. And Fig. 2 of Lindenblad patent No. 2 shows a V-shaped antenna and not the curved wires, that is right, [fol. 263] isn't it?

A. Well, it shows a V-shaped antenna made of straight wires, and I suppose one could call even the curved wires a V-shape antenna, although it would not ordinarily be done.

X Q. 703. So that the only difference between Figs. 2C and 2A and Fig. 2 of the Lindenblad patent is in the precise angle between the legs of the V?

A. I think that is generally correct. I regard the fundamental unit of the Carter third patent antenna as shown in these three figures, 2A, 2B and 2C as a Lindenblad diverging wire antenna, giving the angle for maximum radiation along the bisector, and chosen in accordance with Carter's law relating to the angle and wave length used and the wire length used.

X Q. 704. The only figures of Carter's patent now under consideration which illustrate the complete antenna structure show in each instance the leg of the V, for example, Figs. 4, 5 and 11, the leg of the V, as composed at least of a pair of wires, that is correct, isn't it?

A. Yes; if I understand your question you are referring to the fact that Figs. 4 and 5 show the two-story arrangement that I described, and Fig. 11 the four-story arrangement, neither of which is used in detail by the defendant.

X Q. 705. That is right. Now, is there anything contained in this patent that places any limitation on the length of the antenna wires, that is, the legs of the V?

A. The general statement appears at page 1, line 29——

X Q. 706. I am trying to make time, Mr. Hogan. Can't you answer my question, direct your answer directly to the question?

A. Well, the question is so broad that it is difficult to give [fol. 264] an answer that would be correct without reference to the fact at least that the patent says that the wires are preferably longer than the operating wave length, and that the examples given are of wires five wave lengths in length and eight wave lengths in length.

X Q. 707. But there is no limitation to the advantages to be derived from the specific angle of this patent?

A. I couldn't say that without studying it from that point of view.

X Q. 708. You haven't studied it from that point of view?

A. Not from that point of view; I have always looked at it as a long wire patent.

X Q. 709. Then you would not be able to tell me whether or not I could use a one wave length, that is, an antenna with the legs of the V one wave length long, and obtain the benefits of the particular angle derived in accordance with the teachings of this patent?

A. You would obtain some of the benefits.

X Q. 710. As I recall it, Lindenblad, I think it is Lindenblad No. 2, likewise recommends an antenna length of five to ten wave lengths long, so that in that respect Lindenblad's second patent and the Carter third patent under consideration are in substantial accord, aren't they?

A. They certainly are not in disagreement as to the availability of wires of those lengths.

X Q. 711. Now, at page 4, line 27, the statement is,

"The wires, though preferably placed in horizontal planes may be placed at any desired angle without departing from the scope of this invention, and, during transmission it may often be found desirable to have the plane of the wires [fol. 265] tilted away from the earth and towards the direction in which the beam of energy is to be propagated."

That means the same thing that was stated in one of the prior patents, I think the Lindenblad patent No. 1, that you would tilt the wires in this instance, the same as in the Lindenblad patent, upward, so that they would be at an angle to the earth's surface, is that correct?

A. Yes; which means that you would tilt the wires upward in order to increase the upward angle of propagation.

X Q. 712. Now, refer, please, to page 1, beginning at line 23, where it says:

"It is proposed to place these wires at an angle with respect to each other so that principal radiation takes place along the bisector of the angle. This angle, in general, corresponds to the angle of the principal cone of radiation of one of the conductors."

And that is the same angle that was referred to in the Lindenblad patent No. 1, that is, the first Lindenblad patent, by the reference character, the Greek letter alpha?

A. Yes, the same letter and the same angle.

X Q. 713. And the statement, in so far as it refers to the principal radiation being along the bisector of the angle, the statement is equally true to that extent, of the antennæ shown in the second Lindenblad patent, the V antenna?

A. Why, it is true more strictly in the case of the third Carter patent than in the case of Lindenblad's second, with respect to the concentration of radiation in the general direction of the bisector.

[fol. 266] X Q. 714. So that the difference between them in this respect at least is in degree, is that right?

A. It would be hard to define whether or not it is degree only. The practical results of the use of the Carter angle are very substantial. Certainly the concentration in the line of the bisector in the third Carter patent is much greater than the concentration along the line in the Lindenblad patent because in the Lindenblad second patent, the energy is distributed sidewise in a large part, but in the plane of the wires, as I have said, I think.

X Q. 715. All right. Now, the Carter patent says that the principal radiation takes place along the bisector of the angle between the two legs of the V antenna, is that a correct statement in Carter?

A. Yes.

X Q. 716. And is it a correct statement of Fig. 2 of the second Lindenblad patent that principal radiation takes place along the bisector of the angle; is that statement correct or incorrect for the second Lindenblad patent?

A. It is not correct that radiation takes place only——

X Q. 718. I didn't ask you that. Is it correct or not correct that principal radiation takes place along the bisector of the angle of Fig. 2 in the second Lindenblad patent in suit? Can you answer that yes or no?

A. No, because it will depend on the construction of the Lindenblad antenna.

X Q. 719. What do you mean by construction? What part of the construction will it depend on?

A. The wave length used, the length of the wire, and the angle.

X Q. 720. And isn't that equally true of the Carter patent?

A. Yes.

[fol. 267] X Q. 721 You certainly ignored that in answering my question in respect to the Carter patent.

A. In the case of the Carter patent you have been told how to get principal radiation along the line in large amounts, certainly, to get the very best effect. In the case of Lindenblad's antenna, the second patent, you are told how to use diverging wires to get radiation principally in the plane of the wires, and largely in the bisector. These antennas all have multiple lobes of radiation, and nobody can say in advance, or generally, what will happen for any specific case.

X Q. 722. Then you are drawing a distinction between the word "largely" in respect to the second Lindenblad patent and the word "principal" as employed in the third Carter patent?

A. No, I am not trying to draw any such distinction; I am trying to make it clear to you——

X Q. 723. Do they mean the same thing, "largely" and "principally"?

A. Certainly in many uses.

X Q. 724. And do they mean the same thing as used by Lindenblad and Carter respectively, or don't they?

A. There is no general answer with respect to Lindenblad; with respect to Carter, there is.

X Q. 725. There is some doubt in your mind, is there, that in the second Lindenblad patent, Fig. 2, as to whether or not radiation will be principally along the bisector of the angle of the legs of the antenna? Is there any doubt in your mind about that?

A. I think you are trying to include too many situations in a single question. What I am trying to make clear is that one may define radiation generally in the direction of a line——

[fol. 268] X Q. 726. You are certainly trying to do something other than answer my question.

A. I cannot answer your question because it involves——

X Q. 727. If you will just say so each time, when you don't understand my question, we will both save time.

A. All right, I am trying——

X Q. 729. Now, does the Lindenblad second patent in Fig. 2, and I refer to patent No. 1,927,522, have a structure which is highly directional and consists of a pair of conductors angularly disposed with respect to each other and in which radiant action occurs predominantly along the direction of the axis of the conductor system? Now, yes or no, it does or does not?

A. The answer is yes when "highly" is taken with reference to non-directional systems, but not with reference to more directional systems and when "along the direction of the bisector" is taken as meaning within the plane containing the bisector. I think that is what you mean.

X Q. 730. As far as any radiant action occurring predominantly along the direction of the axis of the system, does the Fig. 2 of the second Lindenblad patent show that or accomplish that? Does the antenna of that figure——

A. It shows a general picture of antennas which will accomplish that result.

X Q. 731. Will it or won't it accomplish it?

A. Some antennas represented by that figure will and some will not. In a strict——

X Q. 732. Does the patent tell you what is necessary to know in order to produce one that will and avoid producing one that will not?

A. It tells you how to produce an antenna in which the radiation is concentrated in the plane containing the bisector, [fol. 269] but as to concentration further within that plane to the line of the bisector, it does not.

X Q. 733. Wait a minute.

A. Well, I have already explained.

X Q. 734. I am going to get a simple answer to this question, Mr. Hogan. I do not care how long it takes. Does the patent, Lindenblad No. 2, and in Fig. 2 thereof, show, and does the patent describe everything that is necessary to know to be able to produce a V-shaped antenna in which the radiant action will occur predominantly along the axis of the conductor system—predominantly along the direction of the axis of the conductor system?

A. Yes, if you take "predominantly along the line of the axis of the conductor system" as a general statement and not one which requires concentration in the geometric line. That is all I have been trying to tell you.

X Q. 735. You didn't say it very simply, then. Is that equally true for Carter 3, the third Carter patent that we have under consideration?

A. The Carter third patent tells how to build a V antenna, which not merely concentrates the energy along the direction of the axis of the system, but within the plane of the wires in a beam along the line of the bisector.

X Q. 736. Then your answer is yes?

A. With the explanation I have given, yes.

X Q. 737. As I understand it, then, your answer is yes, that the Carter system or the Carter antenna, shown and described in the third Carter patent, will give you a system which will enable you to radiate, or in which the radiant action occurs predominantly along the direction of the axis of the conductor system?

A. Yes.

X Q. 738. Now, if you will turn to page 2, line 47, in the third Carter patent, beginning with line 47, there begins a [fol. 270] theoretical consideration in mathematical terms. Have you reviewed those considerations, as well as the formulæ shown at line 60 and line 70 and line 80, to determine whether or not it correctly explains how to obtain this angle between the legs of the V?

A. I think the explanation does give a general picture of the method Carter followed in determining the angle for any specific length of wire, and for any wave length on the wire.

X Q. 739. And the formulæ there given are correct?

A. So far as I know.

X Q. 740. Have you checked them to find out?

A. In a sense. That is to say, I have used V antennas having these angles, and determined that the maximum gain was had with these angles, within practical variations.

X Q. 741. When was that, in the last five or six years?

A. Yes.

X Q. 742. Now, these formulae given at lines 60 and 70 are another way of expressing the angle Alpha that we have referred to in connection with the first Lindenblad patent?

A. Well, they involve a similar angle, although in a different way.

X Q. 743. Will or will not these two formulæ be the angle Alpha of the first Lindenblad patent?

A. They will not be, they will lead to its derivation.

X Q. 744. In other words, you would use this formula to compute this angle Alpha of the first Lindenblad patent?

A. You can use it as a basis for that computation, and have in one case an odd number of half wave lengths, and in the other case, an even number of half wave lengths, but it does not state the angle Alpha explicitly.

[fol. 271] X Q. 745. Do you know of any other formula that could be used for that purpose?

A. No, I have made no study of that kind; that is my understanding of what Carter did, and whether it could be done in some other way, I can't say.

X Q. 746. So that so far as you know this is the only formula capable of figuring out the angle Alpha of Lindenblad 1?

A. No, I am afraid you misunderstood me. I meant that this formula could be used as the basis of deriving the angle Alpha, and the law connecting it to the wire length and wave length. Your last question was such as would imply the empirical formula of line 85, which gives an explicit value of the angle Alpha for any wave length and any wire length.

X Q. 747. This empirical formula at line 85, you meant to include with the first two formulæ?

A. No, I mean that the first two formulæ give a basis for the derivation of Alpha by maximizing or minimizing them as shown here, whereas the third formula at line 85 gives an explicit value of Alpha for any wire length.

X Q. 748. Then I will put it this way: Are these formulæ on 60 and 70 and the empirical formula at 85, are they the only formulæ that you know to enable you to calculate the angle Alpha in the first Lindenblad patent in suit?

A. Yes.

X Q. 749. They are. In this third Carter patent what importance does the height of the antenna above the ground have on this stated object of the invention? Does it have any bearing on it at all?

A. There are three or four objects stated; I am not sure I understand the relation to which or all that you are asking about.

X Q. 750. All of them. I am drawing no distinction. Does [fol. 272] any one of them, I assume it has a bearing as to some of them, tell me that?

A. Yes. We will have to see how Carter states it to answer that. If you want to ask me a specific question, I will answer it directly.

X Q. 751. Is it important to know the height above the ground for any antenna that you would erect under the third Carter patent so as to obtain radiation of waves and so that the principal radiation occurs along the bisector of the angle?

A. If you are referring to the fact that radiation in the plane containing the wires, and therefore containing the

bisector from the antenna alone, results in radiation at an angle of ten degrees or thereabouts upward in its direction of final propagation from the system, including the earth beyond it, which I referred to in my direct examination, then, the height above ground would have a bearing when that height is small compared to the dimensions of the antenna.

X Q. 752. Does the patent give you any instructions as to the height *of* the antenna should be above the ground?

A. Yes.

X Q. 753. Where?

A. It points out at page 3, beginning at line 44, that in practice where the height of the antenna is limited by economic causes and where it is desired to make ground absorption as low as possible, a good compromise is one-half wave length spacing, and then it goes on,

"For transmission of energy having a wave length of 17 or 18 meters, a good practical antenna may be had wherein the lower wires are about three-quarters of a wave length above ground, and the spacing between wires is one-half wave length. 80 foot poles or masts may be used to support the wires."

[fol. 273] That would apply to the two story case, and would put the lower pair three-quarters of a wave length above ground, and the upper pair one and a quarter wave lengths above ground.

Does that answer your question? I think you simply asked if I would say so.

X Q. 754. Yes, I think it does.

A. I did not include in my earlier answer the fact that this reflection effect which tilts the beam upward when the antenna is erected near the ground has no effect on the horizontal directivity we have been talking about. I think I explained that on direct examination, though.

X Q. 755. Now, reference has been made in this Carter patent as to this angle as designated by the Greek letter Alpha?

A. Yes.

X Q. 756. But I notice that where it is referred to in some of the claims of the patent, say, stated in formula form, as well as in page 2, this angle is referred to by the Greek letter Theta, is that correct?

A. Theta is used in the formulas at page 2, line 60 and 70, as an expression for an angle. There you are varying the angle for purposes of determining the desired value—one that gives maximum radiation. When you have determined that angle and you want to consider it, not in terms of variation of angle, but in terms of variation of wire length and wave length, then you use Alpha.

X Q. 757. For example, at Fig. 12, you show the angle as Alpha generally meaning the desired proper angle?

A. That is right.

X Q. 758. But in calculating it in the formula Theta is the unknown quantity, so to speak, that is the proper value of that angle Alpha?

[fol. 274] A. In one sense you are correct, you solve for the Theta which gives you the best condition, and then call that Alpha for that particular condition.

X Q. 759. If you will turn to Fig. 7 of the first Lindenblad patent No. 1,884,006.

A. Yes.

X Q. 760. There one pair of wires is excited by a tap connection to the transmission line?

A. Yes.

X Q. 761. Will you please explain to me what is the little loop that hangs down from the point 46, or rather right under the point 46, at the right hand side of the drawing? What is its purpose and what is its function, and how is it described?

A. It is described generally at page 4, beginning at line 3. I find no specific reference to the portion of the circuit to which you refer. The general purpose of the arrangement is for adjusting or tuning and matching the antenna system, as is explained in the part of the specification at page 4, lines 3 to 32.

X Q. 762. Now, in what respect, I ask you, does that arrangement of tuning and matching differ from the tuning and matching illustrated, for example, in Figs. 2A and 2C of the third Carter patent, if any?

A. Specifically in the adjustment of the so-called trombones shown near the meters 98——

X Q. 763. I am more concerned, Mr. Hogan, with this loop 12 at the bottom.

A. Well, as a mere loop it is much the same as the loop 14 in Fig. 2C of the third Carter patent.

X Q. 764. And the connection with the transmission line is the same, too?

A. They are across this loop, just as in Fig. 2C, although not shown variable.

X Q. 765. And you would have to connect the line 90, the [fol. 275] transmission line, across the loop at the right point, would you not, to obtain the proper impedance matching?

A. Yes.

X Q. 767. Now, I am concerned with the advantages that you have advanced for the third Carter patent, the first of which is that you obtain exceptionally high directivity per unit of the antenna system. In what respect does that differ from the first Lindenblad patent with parallel wires?

A. In that the directivity is greater, both per unit of the antenna and per dollar of cost. I think it is about 50 per cent greater per unit.

X Q. 768. And how does it compare with the second Lindenblad patent, with the V antenna?

A. Very considerably greater than the specific cases shown by Lindenblad.

X Q. 769. Lindenblad shows a specific case?

A. Yes, he recommends five to ten wave lengths and a spacing at the end of one-fifth of the wave length, and I think I gave in my direct examination a gain of about three for such a system.

X Q. 770. That would be very inefficient spacing?

A. No, not very inefficient, but very inefficient compared to what could be had now.

X Q. 771. Of course, the defendant does not employ any such spacing arrangement as that, does it?

A. No, the spacing is much greater at the ends of defendant's wires.

X Q. 772. And the second point is its low cost of erection and maintenance. Is there any difference in this second advantage over the first Lindenblad structure?

A. Yes.

X Q. 773. With the same length of wires, let us say?

A. Yes. This kind of antenna can be supported on three telephone poles that may cost a few hundred dollars apiece or, where a double V is used, by six, whereas the parallel [fol. 276] staggered wire antenna, if it is made vertical, for example, which is one common practical way of using it, the Model B, that requires two rather tall towers and,

where two bays of it are used, of course, four towers. Those towers run from something over a hundred feet to some two hundred feet in height depending upon the wave length that is used, and of course the cost of structures of that sort goes up very fast, something like the square of the height, and depends on the load on the tower, so that the supporting feature is mainly responsible for the saving in cost.

X Q. 774. Suppose you arranged the wires of the Lindenblad 1 horizontally, as is suggested in the patent, you would not need all these additional poles, would you?

A. You would need four poles in that case to support a single structure.

X Q. 775. So that, then, if you did that, the difference in cost between Lindenblad 1 and the third Carter patent would be the cost of one telegraph pole, is that right?

A. No, because you are leaving out the increased directivity, the relative——

X Q. 776. We are talking about cost.

A. We were talking about costs per unit effect, weren't we, or are we talking about cost per unit structure? It does not make any difference to me.

X Q. 777. I am talking about cost in exactly the same language that you used it in your testimony. You said nothing whatever about unit effect.

A. I spoke of it as giving a gain in directive effect and a gain in cost per unit.

X Q. 778. No, you did not. You said you are listing the advantages and the second advantage is its low cost of erection and maintenance.

A. All right, and that can be taken in terms of either [fol. 277] result or of unit. I am simply asking you what you want.

X Q. 779. How did you use it?

A. I have used it both ways now in discussing it with you.

X Q. 780. In terms of cost, how does the third Carter patent compare with the second Lindenblad patent?

A. In terms of cost per unit, they would be the same if the antennas built under them were the same. If the spacing were reduced in the second Lindenblad patent it might be possible to use only one pole to support the ends of the wires, though I think that would not be a practical case. I would say in general the situation was the same.

X Q. 781. The third advantage that you advance for the third Carter patent is its simplicity and stability of adjustment?

A. Yes.

X Q. 782. Have you exactly the same simplicity and stability of adjustment in the first Lindenblad patent?

A. No, it is not quite as simple. I think it is as stable.

X Q. 783. It is as stable?

A. I think so.

X Q. 784. But it isn't quite as simple?

A. No.

X Q. 785. How about the second Lindenblad patent?

A. That certainly is very easy to set up or adjust or tune, and it remains that way, as far as I can see.

X Q. 786. It remains that way?

A. Yes. Its main disadvantage is the relative inefficiency as there shown in detail.

X Q. 787. And the fourth advantage is the fact that it uses standing waves effectively and that there is no need to minimize them either by having exceptionally great length or by using terminal resistors. Is there any advantage there over the first Lindenblad patent?

[fol. 278] A. There is the advantage that the standing waves are used more effectively than in the first Lindenblad patent, but the general——

X Q. 788. In what way?

A. Due to the improved directivity of the system. But the general advantage to the extent that it is present in each structure is the same.

X Q. 789. And there is no difference in this respect between the third Carter patent and the second Lindenblad patent, is there?

A. Yes, there is a big difference there, because in the specific structure, and as far as Lindenblad knew, the standing waves could not be used effectively with his showing. That, I think I have pointed out, he considered as a difficulty which could be solved, that is to say, the antenna efficiency could be increased, the directive efficiency could be increased by reducing the standing waves, as he put it, as a refinement. Carter shows how the sidewise radiation could be not merely reduced, but reduced so that the ultimate efficiency was very high, and without eliminating the standing waves. That is what I am referring to.

X Q. 790. In Fig. 2 of the Lindenblad patent in suit there are standing waves?

A. It may be used either way.

X Q. 791. And you have so construed it in your testimony here?

A. Yes, I think so.

X Q. 792. Now, the fifth advantage is "Its adaptability to successful use with a wide range of lengths of wire and lengths of wave."

Is there any advantage in that respect in the third Carter patent over the first Lindenblad patent?

A. Yes, although it is tied in with the practical difficulty of building the first Lindenblad structure as the wave length [fol. 279] increases. I think this very simple system has got that very definite advantage in that it is more flexible and easily designed to fit a given condition involving considerable changes in wire length and wave length.

X Q. 793. What would be the difference with a horizontal antenna as suggested by the first Lindenblad patent?

A. The difference is principally in the simplicity of this arrangement which gets clear——

X Q. 794. Do not get off of the subject please. I am on the fifth point, its adaptability to successful use with a wide range of lengths of wire and lengths of wave.

A. Yes, and I am trying to put in words for you the fact that this is more adaptable, more flexible and more easily designed than the arrangement of the first Lindenblad patent.

X Q. 795. How about with reference to the second Lindenblad patent?

A. Well, I, of course, consider that the second Lindenblad patent includes this, so that specific cases of the Carter 3 antenna could also be called the Lindenblad second.

In the discussion we have had so far, I have not been doing that, I have been considering the Lindenblad second as that which existed in the practical art prior to Carter's third showing.

Now, with that understanding the adjustability or adaptability, rather, to a large range of wire lengths and wave lengths, is an advantage of the second Lindenblad antenna, but we must remember that its efficiency, as there shown, was low.

X Q. 796. Now, Mr. Hogan, the sixth point of advantage that you enumerated for the third Carter patent, is its high [fol. 280] radiation efficiency, which is usually 90 per cent or 95 per cent. Is that an advantage over the first Lindenblad structure?

A. They both have that advantage.

X Q. 797. How about the second Lindenblad structure?

A. The long wires will have individually high radiation efficiency, and the efficiency will be good; it may not be as high as that.

X Q. 798. And the seventh, "if the side wires are longer than about six wave lengths in length, it has a relatively high directive efficiency for a considerable range of wave lengths in any one structure, that is to say, that the preferred angle becomes less critical for the longer wires."

And the same is true for the Lindenblad second patent, isn't it?

A. Well, the third Carter antenna is within the broad description of the second Lindenblad, and if by that you mean to include it, it is true.

X Q. 799. I do not mean to include anything. Is that same advantage as you have stated with respect to the third Carter patent, does that apply to the second Lindenblad patent as well?

A. It would apply to a set-up built under the second Lindenblad patent, but is not pointed out how such an antenna could be built in the second Lindenblad patent.

*   *   *   *   *   *   *

X Q. 810. Just one more subject and we are through, Mr. Hogan. In connection with this Exhibit E for identification, and in connection with any checking thereof that you may desire to do, I am making the statement to you for additional checking, if you desire, that while the distance between the wires in this instance, as illustrated in this exhibit is 2.04 wave lengths, which I understood you to [fol. 281] believe to be too wide that if this spacing of 2.04 wave lengths, between the parallel wires was increased to 3.09 wave lengths, that you would get perfect addition in the plane of the wires; and similarly, that if they were spaced 5.15 wave lengths, you would again obtain perfect addition of the waves radiating from the wires in the plane of the wires?

X Q. 811. Now, referring to Fig. 2 of the second Lindenblad patent, 1,927,522, will you obtain radiant action predominantly along the direction of the axis of the conductors 6, 2 and 4, irrespective of any angle of the legs of the V, 2 and 4?

A. You will obtain radiation predominantly along the bisector, as a general statement, that is to say, in the plane containing the wires, regardless of the angle, but you will get variations in the predominance along the geometrical line of the bisector depending upon the angle.

X Q. 812. So that at any angle from zero to 90 degrees or 180 degrees, you will obtain predominant radiant action in the direction of the axis or bisector of the angle?

A. I won't say in the line, but in the direction of the plane, that is to say, in that general direction.

X Q. 814. For example, if I draw an angle by erecting an antenna, and put the legs of the V at an angle such as illustrated on this sheet of paper that I show you, I will obtain predominant radiation in the direction indicated by the arrow on that paper in accordance with your last statement?

A. No; I do not know, I may have made it too broad. I have examined cases of the angle which are generally of the order of 45 degrees and less, but not such a wide angle as you show, and it may be that the general direction in that case would be substantially changed, even in the plane, [fol. 282] that is, there may be a dent in the plane of the wires.

X Q. 815. And would it make any difference with respect to the length of the wires of the V in that result?

A. I think the length of the wires would have to be taken into account, yes, surely.

X Q. 816. It is true, isn't it, in considering the radiation from a wire, say, for example, four wave lengths long, that you can consider it as radiation from a point in the wire midway between the ends, that is correct, as a matter——

A. That is one method of analysis, yes.

X Q. 817. Now, as I understand you, you don't know whether or not the radiation in the direction of the axis will be predominant for any angle between the legs of the V, you don't know?

A. That is for all angles?

X Q. 818. Yes.

A. No, it would be true, I think, only in the most general ones. There are so many cases, and they are so complicated that I haven't analyzed anything like a comprehensive group.

X Q. 819. Does the patent, if there is a possibility even that that general statement is not true, does the patent tell you what is the limit of angle between the legs of the V, where it will obtain the results of the patent or where it will not do so?

A. There are no statements in the second Lindenblad patent as to angle whatever and no numerical limits given. There are given a set of recommended cases, wherein the wires are five to ten wave lengths long, and the spacing is about one-fifth the length of the wire.

X Q. 820. Considering in this drawing that I now show you that the legs of the V are four wave lengths long, and that the angle between them is, the full angle, is 122 [fol. 283] degrees, and that it is provided with an impedance matching device between the load and the current source, and the legs of the V are excited separately in phase opposition, and that the usual transmission line is employed between the source of current and the antenna wires. In that arrangement the Vs gradually diverge so that there is a wider spacing at the open ends of the Vs than at their point of connection to the source of current?

A. Well, there certainly is a wider difference between the open ends than there is at the apex, but I wouldn't call that a gradually diverging V.

X Q. 822. What do you mean by a gradually diverging V?

A. I think there is no numerical limit to such a word as "gradually" but for practical purposes, I would expect the angle to be of the order of 45 degrees or less, certainly less than 90 degrees.

X Q. 823. And I think, I want to make it very certain, I think you said in your last answer that the wires, the open ends of the wire in this illustration are certainly widely spaced?

A. I said they were widely spaced compared to the spacing at the apex, yes.

Mr. Darby: May I have this sheet marked for identification?

(Marked Defendant's Exhibit F for identification.)

X Q. 824. My mathematical experts have advised me, Mr. Hogan, that in the arrangement shown on Exhibit F for identification, that rather than obtain radiation predominantly in the direction of the axis or the bisector of the [fol. 284] angle between the antenna, that you will obtain maximum radiation at an angle directly at right angles thereto and will obtain .01 of that amount of radiation in the direction of the axis or the bisector of the angle between the V, as illustrated in this drawing which I show you, and although I will ask to have this marked for identification only, at this time I will supply you with a copy of it, for your check, if you desire to do so.

Mr. Darby: I ask to have this copy of drawing marked for identification.

(Marked Defendant's Exhibit G for identification.)

X Q. 825. I am also advised in that connection, for any value that it may have to you in this matter, that if the angle was changed from 122 degrees between the legs of the V to 120 degrees between the legs of the V, that the amount of radiation in the direction of the axis or the bisector of the angle would be absolutely nothing.

Mr. Darby: That is all.

Redirect examination.

By Mr. Blackmar:

* * * * * * *

R. D. Q. 831. You were also asked this morning with respect to utilization of a single V antenna for a number of wave lengths without change of the structure of the antenna. If you had a single V antenna set up on three permanent masts or poles and wished to reduce the wave length utilized therewith and yet maintain the proper angle between the wires, according to the third Carter patent, could that be done?

[fol. 285] A. Yes, because the angle is dependent upon both the wire length and the wave length; consequently, if, when the wave length was reduced, you will reduce the wire length by cutting off the ends of the wires proportionallly, the angle would remain correct and it would not be necessary to move the poles.

The question I was asked on cross-examination, I think, related to a case in which the angle was to be changed.

Mr. Blackmar: That is all. The plaintiff rests.

Defendant's Proofs

Haraden Pratt, called as a witness in behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Kolisch:

The Witness: I live in New York City. I am vice-president and chief engineer of the Mackay Radio & Telegraph Company, the defendant in this action.

There are two companies in the United States which are associated with the Mackay Company in the wireless business; one operates in the western part of the country, and the other in the eastern part of the country. Outside of the United States, there are companies in Spain, and in most of the important countries of South America and Central America, and Puerto Rico that operate properties that all have radio stations. My relation to those companies so far as the engineering and installation of radio [fol. 286] transmitting stations and receiving stations is concerned is that I am in charge of the engineering and technical maintenance of those plants. I have been engaged in the radio business as an engineer since 1914.

I was educated at the University of California and I graduated there in 1914. I became an engineer for the Marconi Wireless Telegraph Company of America, and I had to do with the supervision of construction of one of its radio stations at Bolinas and Marshall, California. After these plants were constructed I became an expert radio aide in the Navy Department at the Mare Island Navy Yard, and was transferred subsequently to Washington where, during the war, I was in charge of engineering and maintenance and design of all of the high power radio stations operated by the Navy Department. Subsequent to that, in 1920, I was placed in charge of the factory and engineering work for the Federal Telegraph Company and built a system for them, as well as operating the factory

in California. They were engaged in the manufacture of radio telegraph equipment, and they also operated a commercial radio station system, which extended up and down the Pacific Coast, connecting the various cities there by radio telegraph for commercial service. Following that, I did some exploration work and some business for myself, not related to radio.

In 1926, I built a system of communication for the Western Air Express, between Utah and California, when the air mail was instituted, and in 1927, I was placed in charge of development of radio aids for air navigation under the Commerce Department, Bureau of Standards, and I con- [fol. 287] tinued with that work under the direction of the Bureau of Standards until I accepted the position which I now hold, which was in 1928.

During this time, particularly while I was in charge of the radio work for the United States Navy, I had many occasions to inspect radio transmitting and receiving stations. I examined several hundred radio transmitters during this time.

I am an associate member of the Institute of Electrical Engineers and a scientific member of the Institute of Aeronautical Sciences and a fellow and director of the Institute of Radio Engineers. I am a fellow of the Radio Club of America; I am also chairman of some committees and subcommittees in connection with electrical standardization, sponsored by these various engineering societies, and the American Standardization Association. I have also served as technical advisor to the United States Government on the International Radio Station Conference in 1927, held in Washington, and also the engineering technical international organization, which operates under the auspices of the International Convention, which was held at Copenhagen in 1931.

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The antenna systems of defendant at Sayville which are shown in the various exhibits submitted by plaintiff and which are charged to be infringements in this case were installed under my direction.

There are many considerations underlying the construction of these antennae: first, the frequency or wave length, the distance over which you wish to transmit. As to this frequency or wave lengths, the Federal Government as-

[fol. 288] signs certain frequencies for certain stations and one is not permitted to operate on any other frequency, except ordinarily the frequencies that the Government assigns are in the neighborhood of those for which you ask. Those frequencies for telegraph transmission, speaking of these antennas, are in the so-called high frequency range.

Then there is the question of direction in which you wish to transmit; the question of the character of the topography between the transmitting and receiving stations; the general location of the transmission path geographically on the surface of the globe; the amount of land at your disposal; the topography of the land at your disposal; the electrical characteristics of the ground on which the antenna is to be built; the amount of directional effect, perhaps, that you wish in the particular case; the amount of undesired radiation with regard to the direction in which you wish to send desired radiation; the use of existing structures, if available, are taken into consideration, that you may have on your property; also the amount of money that you feel you can invest to justify the type of service for which you wish to use the antenna.

The Court: That comes first, doesn't it?
The Witness: Usually it does.

All these antennae and each of them is built to operate on one frequency and one frequency is used. I have had experience with these particular antennæ or with other antennæ installed by me or under my supervision in which the antenna was changed so as to take care of a different frequency; I made many such changes. I have made such [fol. 289] changes at Sayville. Antenna No. 11 was changed at one time for two reasons, change in frequency and also a change in direction. Antenna No. 7 was changed at one time, but that was for change in direction. Antenna No. 11 was an example of a change of antenna of the same type as are shown in these exhibits showing antennas Nos. 1 to 11, which are charged to infringe, where the change had solely to do with the operation of the antenna on a different frequency. If it had not been necessary to change the direction, the antenna would have to have been changed on account of frequency. In order to make this V antenna operate on a different frequency, the poles supporting the outer ends of the wires were moved so as to change the angle between the wires. As to the cost in any one instance

that I recall of changing the frequency, where it was necessary to change the antenna on account of a change of the frequency on which the antenna was operated as compared to the cost of installing a new V type antenna, I can only make an approximation. It might run from fifteen to twenty per cent., perhaps of the original cost. It was necessary in each case, in addition to moving the poles, to retune the antenna.

* * * * * * *

Referring to the antennas Nos. 1 to 11 at Sayville, I do not know of any case where radiation is propagated predominantly in the plane of the wire.

Cross-examination.

By Mr. Brown:

The Witness: I said in connection with the Sayville antennas that the signals were not propagated predominantly [fol. 290] in the plane of the wires. They were propagated in the vertical plane containing the bisector of the angle of the wires.

X Q. 129. What you mean by saying they were not propagated in the plane of the wires was that they were tilted upwards slightly from the horizontal plane of the wires?

A. If you are referring to the maximum direction or the direction of the maximum amount of radiation, they would be tilted up.

X Q. 130. I am referring to the same thing you were referring to.

A. That is what I was referring to.

I spoke yesterday about changing the direction of some of the antennas at Sayville. By "changing the directions" I meant the destination to which the signals were intended to go was changed from one place to another. I brought about that change of direction by moving the wires so that they would lie in a different place than they did before. In bringing about this change of direction, the bisector of the angle of the V was changed, of course, when the wires were changed. That was changed from the original destination to the new desired destination, so that the bisector of angle which formerly bore on one particular point was

changed so that the bisector of the angle of the V bore on the new destination.

* * * * * * *

I was the engineer in charge of construction of the defendant's antennas at Sayville. I told the Court the considerations which impelled me to the choice of the particular antennas that were there. I recall stating the conditions that would confront one in designing any kind of an antenna system. That is what I meant in citing the conditions that [fol. 291] influenced me in designing those antennas. I can say that the antennas which were constructed were decided upon in view of all those considerations. The V antennas that I put up at Sayville were the most effective that I knew of at that time, for the amount of money that I wished to spend on them.

* * * * * * *

To put up one of our double V antennas at Sayville it costs perhaps two to three thousand dollars. Whether that is the total cost of original installation depends on whether you are talking about book value or local cost. I mean local cost, that is the cost of labor and material.

* * * * * * *

The designing of the defendant's antennas at Sayville, that is, those that are involved in this suit, was done under my direction. Mr. Kelley did not have any part in it.

I spoke of having seen a great many transmitting stations. As physical structures, the first ones that I saw that had an antenna in the form of a V with long straight wires, long in terms of wave lengths, and excited in phase opposition, were those which we erected at Sayville.

Redirect examination.

By Mr. Kolisch:

The Witness: I saw plans and drawings of antennæ having wires of the wave lengths such as described in my last answer in 1930. I saw them in our office in New York where they had been prepared for erection abroad. Those drawings were prepared by the Radio Engineering Department of the International Telephone & Telegraph Corporation.

[fol. 292] At the beginning of my cross-examination something was said about a tilt, referring to antennæ Nos. 1 to 11 at Sayville. In none of these eleven antennas are the wires titled with respect to the horizontal.

LEO A. KELLEY, called as a witness on behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

Q. 1. Mr. Kelley, where do you reside?
A. Jackson Heights, New York.
Q. 2. What is your occupation?
A. Consulting engineer.
Q. 3. Will you please state your education, training and experience which qualifies you to testify as an expert in this case involving the subject matter of matching impedances and antenna structure and operation?
A. Yes, sir.

I graduated from the Massachusetts Institute of Technology in 1918.

I specialized in radio engineering under the instruction of Dr. A. E. Kennelly, at Cruft Laboratory at Harvard University.

Along with my engineering training I had a complete course in problems connected with transmission lines and the transmission of energy over transmission lines, which included closing the end of the transmission line in surge impedance in order to prevent reflection of energy back over the transmission line.

Directly after my graduation from the Massachusetts Institute of Technology I was in the United States Signal [fol. 293] Corps over a period of approximately six months, and I spent part of the time at Yale University and also at Camp Albert Vale in continuation of the radio work in which I had received instruction at M. I. T.

From 1920 to 1925 I was a member of the engineering staff of the Western Electric Company, what is now known as the Bell Telephone Laboratories.

One of the first projects in which I was working was the Havana-Key West submarine telephone cable. It was on

this project that I first became acquainted, through actual experience, with the use of impedance matching transformers for terminating transmission lines.

In general, over that period, I was engaged in the development of high frequency signaling systems which were called carrier telephone and telegraph systems, and are also known by the popular name of wired radio. The late General Squire was the one who, I believe, gave them that name.

I had considerable experience with these high frequency signaling systems operating over a variety of transmission lines,—the submarine cable of which I have already spoken, and an aerial cable, and open wire lines. The latter type of transmission line corresponds to the type that occurs in the patents in suit.

In addition to this I carried on an investigation on the transmission of a multiplicity of signaling currents of different frequencies over the Havana-Key West submarine cable.

From 1925 to 1929 I was an engineer with the American Telephone & Telegraph Company in the Department of Development and Research. There again I continued my [fol. 294] work with the high frequency signaling systems, but I worked more intensively on the transmission of such signals over the long distance transmission lines of the American Telephone & Telegraph Company.

I also investigated, over a period of years, the interference caused by static or lightning induction on these long transmission lines while signals were being transmitted over them. I had at my disposal during this time, for the tests, something over 2,000 miles of these transmission lines.

From 1929 to 1932 I was on the engineering staff of the International Communications Laboratories, where I developed a new type of carrier telegraph system, which was installed between New York and Washington on the lines of the Postal Telegraph Company, and this system is still in commercial service.

From 1932 to the present time I have been engaged in general engineering and consulting work, mostly connected with signaling or communication systems.

I have been a member of the American Institute of Electrical Engineers and the Institute of Radio Engineers for a period of years.

I have presented a paper before the American Institute of Electrical Engineers, and also before the Radio Club of America.

I have also delivered two lectures at the Massachusetts Institute of Technology on the subject of a new method of designing electric wave filters.

* * * * * * *

Q. 42. Are you familiar with the defendant's antennæ as illustrated in the drawings which are here in evidence under [fol. 295] stipulation as correctly showing the defendant's antennæ?

A. Yes, sir.

* * * * * * *

Q. 53. Referring to the defendant's antenna, and we will take the simplest form, antenna 2, as illustrative in these respects of all the antennæ of the defendant; do you agree with Mr. Hogan that the transmission line is the line which extends from the transmitter to the points CD?

A. Yes, sir.

Q. 54. Do you likewise agree with Mr. Hogan that the energy radiating circuits in all these antennas consist of the wires AC and BD?

A. Yes, sir, they are the only part of the system which radiates to any extent.

* * * * * * *

Q. 242. With particular reference to the tuning arrangement employed by the defendant in its antennas, will you now refer to the first Lindenblad patent in suit. I call your attention particularly to Fig. 7 of the first Lindenblad patent as well as to Fig. 2C of the third Carter patent in suit, and I will ask you to please first describe the tuning arrangement of the Lindenblad patent, and compare it respectively with the third Carter patent in suit 2C, and the defendant's antennas arrangement.

A. Referring to the Lindenblad patent, a tuning arrangement is shown, marked 46, consisting of a trombone slide. That is the only difference, this being a minor difference, that instead of lengthening and shortening the legs by means of the cross bar, the cross bar is always connected

and the length is changed by sliding in and out like a trombone.

[fol. 296] The tuning is done by the lengthening and shortening of this member, and the points marked with circles right near the numeral 46 in the Lindenblad Fig. 7 correspond to the arrowheads marked 18, Fig. 2C, of the Carter patent, third Carter patent in suit.

Q. 243. If I may interrupt there, Mr. Hogan testified with respect to this loop of the Lindenblad patent, in answer to X Q. 763, "as a mere loop it is much the same as the loop 14 in Fig. 2C of the third Carter patent". Do you agree with that?

A. Yes, sir, that is what I have just described.

Q. 244. He was then asked, "And the connection with the transmission line is the same, too?

A. They are across this loop, just as in Fig. 2C, although not shown variable." The next question: "And you would have to connect the line 90, the transmission line, across the loop at the right point, would you not, to obtain the proper impedance matching? A. Yes." Do you agree with Mr. Hogan's testimony with respect to this loop of the Lindenblad patent?

A. Yes, sir, I do.

Q. 245. Now, will you compare the loop arrangement of the Lindenblad patent with the loop arrangement employed in the defendant's antennas in so far as it is used for the same purpose as used in Fig. 7 of the Lindenblad patent?

A. It is the same.

Q. 246. Have you any particular antenna in mind or does that apply to all of the defendant's antennas?

A. As far as I know, it applies to all.

*   *   *   *   *   *   *

Q. 292. Referring to defendant's antenna, in the case of any antenna employed by defendant, is the propagation of the radiant energy predominantly in the plane of the wires?

[fol. 297] A. No, sir, the radiation is sent out at a considerable angle, a substantial angle, to the plane of the wires.

Q. 293. Is that accomplished accidentally or as matter of design?

A. That is accomplished as a matter of design.

Q. 294. For a particular purpose?

A. Yes, for the——

Mr. Blackmar: If your Honor please, I do not know whether this witness has any knowledge of the design of these antennas. I don't know if this witness is qualified as to the design of these antennas.

The Court: I don't know; he testified to familiarity, and I suppose he knows.

Q. 295. What is the purpose of propagating the radiant energy from defendant's antennas at an angle to the plane of the wires?

A. The purpose is to make use of what is known as a sky wave so that, as is well known in short-wave radio systems, the energy can be reflected from the upper ionized layers of the atmosphere, and consequently sent to great distances.

Q. 315. Now, in so far as making a unidirectional antenna is concerned, will you please compare Figure 5 of the Lindenblad patent with Figs. 3 and 4 of the first Carter patent in suit, No. 1,623,996?

A. The same principle of spacing and phasing is employed in each case. For unidirectional radiation from a bidirectional system it is always necessary to space the individual radiators an odd number of quarter wave lengths apart in the direction in which it is desired to transmit or propagate any one of the two opposite directions and can- [fol. 298] cel in the other of the two opposite directions, the difference in time phase between the currents fed to the individual radiators being quadrature or 90 degrees apart and thus two conditions would have to be obtained, that is, that spacing and phasing would have to be obtained in order to change from bidirectional to unidirectional system, regardless of the character of the individual radiators that enter into the combination.

Q. 320. Will you please turn to the second Lindenblad patent in suit No. 1,927,522 and consider it with reference to its bearing on the antenna employed by defendant in so far as the subject matter of the patent permits you to do so?

A. The second Lindenblad patent refers to an antenna of the traveling wave type, of which defendant has none.

The nature of the second Lindenblad patent is very clearly contained on page 1 of the specification beginning with line 3, "Short wave antennas suffer from the disadvantage of having to be rather critically tuned to the working frequency and from the further disadvantage of necessitating the use of some kind of an impedance matching device between the antenna and the transmission line connecting the antenna with the radio equipment. It is an object of my invention to provide an exceedingly simple form of short-wave antenna which will operate over a considerable range of frequency, and a further object of my invention is to provide an antenna with which a transmission line may be coupled without the use of intermediate impedance matching devices."

The description of the present Lindenblad invention referring to that which he would avoid clearly indicates that [fol. 299] it is not for an antenna of the standing wave type, but an antenna of the traveling wave type.

An antenna of the standing wave type by its very nature should be tuned for best operation. Furthermore, some kind of impedance matching device should be used with a standing wave antenna for connecting from the transmission line to the antenna, and both of these elements which are so necessary in the case of the standing wave antennæ, in accordance with the passage I have just read, are to be avoided by the use of this second Lindenblad patent.

Q. 321. Will you look at these two drawings which are marked for identification as Defendant's Exhibit A? Did you hear Mr. Hansell's testimony as to the type of antenna that would give that type of pattern?

A. Yes, sir, I did.

Q. 322. Do you agree with his testimony in that respect?

A. As I recall it, he said it would be the radiation pattern from a traveling wave type antenna.

Q. 323. Do you agree with that?

A. Yes, sir, I do.

Mr. Darby: I offer the drawings in evidence.

(Defendant's Exhibit A for identification now marked Defendant's Exhibit A in evidence.)

Q. 324. Will you refer to the passage contained in the Lindenblad patent beginning at page 2, line 93, that portion

which refers to the image. I want you to discuss the subject of the image.

A. "In connection with Figs. 3 and 5,"—I am now read- [fol. 300] ing from the passage that you indicated, "the desired radiation will, of course, take place in the direction of the axis of the transmission line 24 and the diverging conductors. Taken from another point of view, we can consider merely the upper half of Figures 3 and 5 as being in a vertical plane with its image in the ground; we will then have two serially connected conductors (conductor 26 and the upper antenna leading to transmission line 24 in Figure 3). Radiation will occur substantially in the direction of a line perpendicular to the bisector of the angle between these two conductors."

He says in effect here that the two sides of the system, that is, the sides forming the V and cross back and forth, which are excited in phase opposition, may be replaced by what is the same thing, the omission of one side of this entire system, the side being omitted being replaced by the surface of the earth and the reflection of the remaining side in the ground, that is, the image of that one side in the ground will co-operate automatically in phase opposition so as to give substantially the same result as was obtained formerly with the two wires inclined at an angle to each other and excited in phase opposition.

Q. 326. Do you agree with the statement made in the Lindenblad patent?

A. Substantially, yes, sir.

Q. 327. Is or is not this subject of image or mirror in the earth an accepted principle in radio work, that you have been connected with?

A. Yes, sir; in fact, it goes back quite a long time and it has been almost the universal custom of those in the art to consider the ground to be a perfect mirror for electric [fol. 301] waves so that whatever radiation occurs from a structure above the ground, in operation one must consider the effect of its image in the ground either to enhance its radiation or to destroy.

Q. 328. During the prosecution of this Lindenblad patent, Lindenblad presented some claims to the Patent Office which the Patent Office rejected because of want of disclosure in the patent. As a result the patentee, Lindenblad, then the

applicant, wrote a letter to Mr. Brown of the Patent Department of RCA Communications, and that letter was made a part of the File Wrapper of the application in the Patent Office. One statement that is made in it is as follows:

"I believe it requires no argument that one-half of the system with an image in the ground functions as is claimed to obtain radiant action principally in the direction of a line perpendicular to the bisector of an angle between the conductors of half the system. The theory of images as first developed by Lord Kelvin has time and again been used and proved, especially in the radio art, and also in other branches of the electrical art. It is one of the axioms on which we build our theories of propagation and is an accepted fact."

Do you agree with that statement, Mr. Kelley?

A. Yes, substantially.

Q. 329. Now will you please direct your attention to the subject of the spacing between the open ends of the radiation wires of the second Lindenblad patent and its relation to the stated objective of the patent?

[fol. 302] A. Well, in the first place, Lindenblad in his patent desires to obtain a traveling wave type of antenna by making the antenna itself long enough so that as the energy is radiated out on the antenna, ultimately most of it will be consumed, and by making distinctions with the traveling wave antenna of the prior art, where terminations in the form of a resistance or other energy consuming devices were connected to the outer ends of the antenna, Lindenblad here desires to obtain the same result without such termination, by making the antenna wires long enough so that the energy is practically all radiated by the time it goes to the outer end of the wires, and consequently there will be practically nothing to be reflected and it is only by the mingling of the outward flowing energy and reflected waves on the antenna wires that the standing waves are produced, and in the absence of standing waves one has a traveling wave type.

In this case the energy is to be consumed on its way out. Such an antenna would have to be of considerable length, as Lindenblad recognizes.

On page 1, line 47, he states:

"To lessen the standing wave I reduce the reflected energy by radiating as much of the energy fed to the antenna as possible. To merely increase the dimensions of the antenna is not practicable, for to increase the length without increasing the spacing, that is, to decrease the angle of divergence, does not increase the radiation, and on the other hand, to keep the same angle of divergence necessitates so wide a spacing as to make the antenna structurally incon-[fol. 303] venient. To overcome this I employ a plurality of antennas or pairs of diverging conductors, arranged end to end, so as to radiate cumulatively."

To paraphrase what he states in this passage, he recognizes that he must have the antenna long enough to consume a very large part of the energy. He recognizes also that ~~merely to~~ lengthen the antenna without at the same time keeping the spacing in the same direction to such an extent that this objective could be reached would certainly not be practical, because it would call for absurdly wide spacing at the outer end.

In order to avoid that, he arranges the wires as in Figs. 3 and 5 in the specification, crisscrossing them, that is, alternately diverging and converging with phase changing arrangements whereby he hopes to get a cumulative effect equivalent to what he would have gotten had he extended the wires straight on out the same length, and by this crisscrossing arrangement saving this extra space required by very long antenna wires.

Q. 330. Now referring to Fig. 2, for example, is there any relation between the spacing of the open end of the wires or the angle of the V and having the radiant action occur preeminently along the direction of the axis of the conductor of the system, in other words, must there be the proper angle of the V?

A. There should be a proper angle of the V.

Q. 331. Must there be a proper angle of the V?

A. There must be a proper angle of the V in order to obtain the radiant action largely in the direction of the bisector of the angle.

[fol. 304] Q. 332. Have you had prepared drawings illustrating a condition which might happen if the angle is not correct?

A. I have.

Q. 333. Will you please refer to these drawings which have been marked for identification Defendant's Exhibits F and G and describe what they represent?

A. Exhibit F merely shows diagrammatically the arrangement of the wires of a V forming an obtuse angle and excited in phase opposition.

Exhibit G shows, on an enlarged scale, the same V, that is, same angle V, each side of which is four wave lengths long, and on each leg of the V is shown the radiation pattern that would be obtained by the wire forming that leg of the V alone.

The radiation from this V-shaped antenna, as a system, that is, combined radiation from the two sides of the V, will be predominantly not along the axis of the system, but directly at right angles thereto; and, for comparison, if we represent the radiation at right angles to the axis of this system by the figure 400, the radiation along the axis of the antenna system would be represented by the figure 4. In other words, only one per cent in the direction of the axis of the conductor system, as compared with radiation in a direction perpendicular to the axis of the conductor system.

Q. 334. Is there or is there not some particular angle between the legs of the V at which you would obtain no radiation in the direction of the arrow?

A. Yes, practically zero radiation may be obtained by adjusting the angle of the V slightly from the position indicated in Exhibit G.

Q. 335. Would the change from zero radiation in the [fol. 305] direction of the arrow to a predominant radiation in the direction of the arrow be in a gradual scale from the zero position of the V to some other position closer together for the legs, at some narrower angle? In other words, is it an abrupt change or does that position——

A. Well, it is both an abrupt change and a gradual one, inasmuch as the minor lobes keep going in and out, so to speak, until quite a different angle is reached where addition is in the direction of the bisector predominantly.

Mr. Darby: I offer in evidence the drawing, Defendant's Exhibit F for identification and the enlargement, Exhibit G for identification.

(Marked Defendant's Exhibits F and G in evidence respectively.)

Q. 336. Referring to these two patterns, Defendant's Exhibit A, could one get the radiation pattern of Exhibit A with the antenna structure shown in Fig. 2, assuming that the wires are short enough to operate as a standing wave antenna?

A. Not at all. The result, even if the radiation were predominantly along the bisector of the system, would be bi-directional, that is, it would radiate strongly in two opposite directions, whereas the diagram shown on Exhibit A radiates predominantly in one general direction.

Q. 337. Could one obtain the radiation pattern illustrated in Exhibit A from an arrangement such as Fig. 3 or Fig. 5 of this Lindenblad pattern or Fig. 1?

A. If it could be obtained at all, it would have to be obtained with a very long antenna of the type of Fig. 3 or Fig. 5.

[fol. 306] Q. 338. How about Fig. 1?

A. If it were long enough.

Q. 339. What do you mean by long enough?

A. I really don't know how long, but certainly longer than anything that we are considering as regards defendant's antennæ which are of the standing wave type. It would be much longer than that.

Q. 340. Do you find any instructions in the Lindenblad patent as to the proper angle between the legs of the V antenna shown in Fig. 2?

A. No, I don't.

Q. 341. Do you find in the Lindenblad patent instructions as to the necessity for or how to obtain the angle between the legs of the V of Fig. 2 in order to obtain radiant action predominantly along the direction of the axis of the conductor system?

A. I don't.

Q. 342. Will you now turn to the third Carter patent in suit, No. 1,974,387 and first direct your attention to pointing out the difference between the disclosure of the third Carter patent and the disclosure of the first and second Lindenblad patents?

A. Comparing the third Carter patent with the first Lindenblad patent, the first similarity is in the element of the radiators with which the systems are constructed, the radiation diagram of Fig. 1-A of the third Carter patent, being the same representation as the radiation diagram from the single wire of the Lindenblad patent, Fig. 2.

In both cases the angle which the radiation makes with the axis of the wire is labeled Alpha. These two diagrams represent the same thing. They are simplified diagrams of which Fig. 1-B of the Third Carter patent is typical.
[fol. 307] In other words, the so-called minor lobes of radiation, the many smaller lobes in between the principal lobes are omitted for simplicity.

The radiation diagram of Fig. 1-B, which shows more in detail what the smaller form, shown in Fig. 1-A indicates, is obtained from a well-known formula which was developed by Abraham, and to which I shall refer later in more detail.

Q. 343. About when was it developed?

A. We have references to 1898. There was an article in 1898, and another article in 1901, both relating to the derivation of these formulae from two different standpoints, one was of quite rigorous derivation, and the other was derived using a convenient and practical assumption which is customary in the art today.

Q. 344. Proceed with your comparison, please.

A. So that the first Lindenblad patent utilizes the same radiation diagram as the third Carter patent. It utilizes the same principal lobes of radiation determined by the same formula, the only difference being that one set of lobes is used for obtaining a perfect combination in a desired direction by using parallel wires, which is the case of the first Lindenblad patent, whereas the third Carter patent utilizes the same radiation pattern and the same angle of principal radiation, but including the wires to each other, so that another set of lobes will add in preference to the ones that added when there were two parallel wires.

Q. 345. And in that respect the third Carter patent is the same or different from what was intended to be accomplished by the second Lindenblad patent?

A. It is the same as was intended to be accomplished by [fol. 308] the second Lindenblad patent.

Q. 346. And what does the Carter patent teach as to the plane of the propagated waves relative to the radiating wires?

A. The third Carter patent arranges the wires of the V in such a manner that these principal lobes of radiation, of which I just spoke, on the inside, so to speak, of one wire, with the principal lobe in the inside of the other wire, so it all will come together when the angle between the principal

lobe of radiation and the wire is equal to the angle to the bisector of the two wires, in other words, that these lobes will now combine exactly in the plane of the wire and along the direction of the bisector.

Q. 347. And is "along the direction of the bisector" or is it not, in the same plane of the wires?

A. Yes, the bisector of an angle is always in the same plane.

Q. 348. I believe you have already testified that none of the defendant's antennæ propagate waves in the same plane of the wires, but at an angle thereto. Is there any benefit obtained by doing that, and I now refer particularly to gain in propagation?

A. Yes, sir, there is. It is fundamentally necessary in working with short waves to direct radiation not in a horizontal plane direct, but at some angle to the horizontal, in order to carry on long distance communication successfully.

Q. 349. Have you had radiation patterns made illustrating the radiation in a direction along the bisector of the angle of the conductors, and what it actually is in defendant's antennæ, where the propagation is at an angle to the plane of the wires of the conductors?

A. I have.

[fol. 309] Q. 350. Will you please produce the chart of defendant's antenna No. 8 on which that sketch has been made and describe what is there shown?

A. Yes, sir; referring to the upper left-hand diagram, which shows what the radiation would be between the wires of a V, making an angle of 45 degrees with one another, there is shown the radiation pattern with minor lobes largely omitted.

Q. 352. In defendant's antenna No. 8, the angle between the legs of the V is 45 degrees, is that right?

A. That is right. This is the pattern that would be obtained in free space without obtaining the benefit of ground reflection.

Q. 353. Is that the pattern that would be obtained in the plaintiff's conductors?

A. That is a pattern that would be obtained in the plaintiff's conductors. The right-hand pattern shows the actual beam which is sent out and inclined at a substantial angle to the horizontal, the wires of the V being in a horizontal plane, consequently the main radiation takes place at an angle to the plane of the wires of the V.

Q. 354. Does the main radiation take place along the bisector of the angle?

A. No, sir.

Q. 355. In the left-hand figure does the radiation take place along the bisector of the angle?

A. Yes, sir.

Q. 356. Will you please explain the significance of the lower pair of diagrams as well as the significance of the 50 degree angle?

A. The angle of 50 degrees between the wires is the angle that would have been used had the instructions of the third Carter patent been followed, where actually in defendant's structure, the angle is 45 degrees. The reason for this [fol. 310] being that by using this angle different from the angle recommended by Carter, in his third patent, a larger lobe of radiation is obtained when an actual structure cooperating with the ground, its image in the ground, radiates at an angle inclined to the horizontal.

The radiation, the ultimate objective, so to speak, that which goes out to the receiving station, is greater by using the angle of 45 degrees with the same length of wire than it is by using the same V, but an angle of 50 degrees, as is recommended in the third Carter patent.

It was done at an apparent sacrifice as will be seen by comparing the two left-hand figures.

This upper left-hand figure represents the theoretical radiation, or in other words, the radiation in free space from the V of defendant, at an angle of 45 degrees, whereas the radiation in free space, using the angle recommended by Carter of 50 degrees, gives a somewhat greater theoretical radiation in free space, but it is not usable. One must build antenna structures with some relation to the ground, and if properly related to the ground, the ground could be made to enhance that radiation.

The right-hand figures show the reversal of the advantage that appeared to be obtained when the radiation was considered as free from the ground.

In other words, the upper left-hand figure, where the angle is 45 degrees and corresponds in defendant's antenna, the radiation is somewhat less in this direction than it is for the angle of 50 degrees in that same direction, but for the radiation which actually goes out, that is, the ultimate usable radiation, is greater as seen by comparing the two right-

[fol. 311] hand patterns where the distance numerically is 31 for the upper right-hand pattern and about 28.6 for the lower one.

Q. 358. If it has been suggested in this case, that by defendant's departure from the angle recommended by the Carter patent in suit by five degrees, the defendant has sacrificed anything in the efficient propagation of its waves, do you agree or disagree with any such suggestion?

A. I disagree.

Q. 359. And does this chart which you have been describing illustrate the reason for your disagreement?

A. Yes, sir, because the apparent sacrifice is turned into a real gain.

Q. 360. And when you say "apparent sacrifice", what do you mean? Do you mean apparent from theoretical considerations or from practical considerations?

A. I mean from practical considerations.

Mr. Darby: I now offer in evidence the chart referred to by the witness:

(Marked Defendant's Exhibit S in evidence.)

The Court: Did the patentee limit himself to that 50 degree angle, or was that just a suggestion?

The Witness: The patentee gives the proper angle for a given length of side in electrical length in Fig. 12 of the specification, and in this Fig. 12, the angle 50 degrees corresponds to the one that he draws a curve for, so that that is the angle which he says should be used.

Q. 361. Now, will you state whether or not the same is true [fol. 312] with the other antenna of the defendant, which is concerned with this question, defendant's antenna No. 2?

A. Yes, sir.

Q. 362. Have you made a similar pattern and comparative diagram showing what the radiation pattern would be in direction along the bisector of the angle of the conductors in the plane of the wires, at an angle of the V of 35 degrees such as employed in antenna No. 2, and what it actually is and what it would be in both instances if the angle of the V were 35.6 degrees?

A. I have had such a diagram made.

Q. 363. And does the same relation that you have described with reference to defendant's Exhibit S apply to defendant's antenna No. 2?

A. The same considerations apply to antenna No. 2, yes, sir.

Q. 364. And are the same results obtained?

A. The same results are obtained, yes, sir.

Q. 365. And do you draw the same conclusions?

A. Yes, sir, the two upper diagrams here correspond to defendant, and the two lower, if the angle from Fig. 12 of the third Carter patent were used.

Q. 366. Are these diagrams that you have referred to with reference to defendant's antennas Nos. 8 and 2, are they typical and apply equally as well, differing quantitatively, of course to all of defendant's antenna?

A. Yes, they are typical.

Mr. Darby: I offer this other diagram in evidence, which has been referred to by the witness.

(Marked Defendant's Exhibit T in evidence.)

[fol. 313] Q. 367. With reference to the third Carter patent in suit, No. 1,974,387, does that patent teach in what plane relative to the plane of the wires predominant radiation is obtained?

A. Yes, sir, it does.

Q. 368. Just a minute. I had not finished my question. Does the patent teach in what plane relative to the plane of the wires predominant radiation is obtained by an antenna constructed in accordance with the disclosure of the patent?

A. Yes, sir, it does. It teaches that predominant radiation is obtained along the bisector of the angle formed by the wires, and in the plane of the wires.

Q. 389. If the wires were arranged horizontally to the earth, in what plant would the predominant radiation occur, as taught by the third Carter patent in suit?

A. As taught by the third Carter patent in suit, the predominant radiation would then occur in the horizontal direction in the plane of the wires which, as you say, are horizontal.

Q. 390. Will you refer to the third Carter patent in suit and point out the instances where the patent teaches this?

A. Referring first to page 1, line 62:

"To increase horizontal directivity, the arrangements of wires may be duplicated side by side."

This reference refers to an arrangement of the V where the wires are horizontal with respect to the ground and this

means that the directivity, that is to say, the predominant radiation is in the horizontal direction, in the plane of the wires.

[fol. 314] Again on page 1, I find still another instance, line 74:

"Figures 2a, 2b and 2c indicate various forms of the fundamental unit of the present invention wherein long linear conductors having standing waves thereon are disposed at an angle such that principal radiation occurs along the direction of the bisector of the angle."

Here again the same idea is expressed, namely, that predominant radiation, as taught by this patent, is along the bisector of the angle formed by the wires, that is, along the plane of the wires.

Again, on page 2, line 29:

"Now, if it is desired to radiate energy principally in the direction of axis X-X of Figures 2a, 2b, and 2c, the conductors, shown in Figure 1, should be turned an angle Alpha relative to the direction X-X; and, in order to increase still further the directional characteristic along the axis X-X, according to the present invention, two wires are used each of which makes an angle Alpha with the axis X-X on opposite sides of the axis in a fashion such that the axis and the pair of wires lie in a single plane."

This again means that the predominant radiation would be along the axis X-X, which is the bisector of the angle formed by the wires, hence in the plane of the wires.

Also on page 2, line 42:

"Consequently a pair of wires disposed at the angle [fol. 315] Alpha with respect to the X-X axis will have a radiation characteristic in the plane of the pair of wires of the general type shown in Figure 3."

This again means that radiation is predominently along the axis of the bisector of the angle formed by the wires, hence, predominently in the plane of the wires.

Again on page 2, line 97:

"The fundamental unit is shown in Figure 2a where a transmission line 10 supplies high frequency energy to a pair of wires A, B forming the angle 2 Alpha with each other. The angle Alpha is the angle made by one of the

conductors with the X-X axis along which it is desired that the radiators A, B, propagate energy."

Here again the same idea is expressed, that radiation is predominantly in the plane of the wires.

On page 3, line 71:

"That is, Figure 5 illustrates a system such as shown in Figure 4 duplicated in a direction along the X-X axis whereby, in a horizontal plane, a directional characteristic is obtained such as that shown in Figure 6 and, in a vertical plane a power distribution characteristic such as shown in Figure 7."

Q. 392. Will you just interrupt long enough to refer to Fig. 6, and point out how the figure there shown is consistent with that description?

A. Referring to Fig. 6, the designation below the figure is "Power Distribution, Horizontal Plane." The wires [fol. 316] of the structure which refer to Fig. 6 are in the horizontal plane, and consequently this means the radiation which takes place in the horizontal plane, that is, in the plane of the wires.

Q. 393. All right, proceed to the next one.

A. On page 3, line 86:

"Consequently, energy will be propagated principally along the axis X-X towards the diverging ends of the radiators."

The same idea of radiation in the plane of the wires is taught in that passage.

And, again, page 3, line 110:

"Thus, in Figure 8 each of the radiating units A, B shown in plan view is provided with a reflecting unit a, b. By means of branched transmission lines, as shown diagrammatically at T, each system is fed cophasally as a result of which an extremely concentrated beam of energy in the plane of the units is transmitted in a direction from the reflecting units towards the radiating units or the reverse, depending upon the relative phase of the standing waves upon the units."

This again means that the radiation is predominantly in the plane of the wires.

Again, on page 3, line 124:

"By making the phase difference between each of the units equal to 2 pi S divided by Lambda, where S is a spacing of each unit measured along the axis, concentrated unidirectional propagation may be obtained in either direction along the X-X axis depending upon whether or not the [fol. 317] standing waves on the succeeding units lag or lead each other by the phase difference given according to the foregoing expression."

This again teaches the same thing as the other passages which I have read.

On page 4, line 3:

"By suitable tuning and by suitable spacing of the radiating pairs of wires and reflecting pairs of wires, unidirectional propagation may be obtained in either direction along the bisector of the angle formed by the wires of each pair."

This again teaches that predominant radiation is to be obtained in the plane of the wires, and along the bisector of the angle formed by the wires.

And, finally, page 4, line 27:

"The wires, though preferably placed in horizontal planes may be placed at any desired angle without departing from the scope of this invention, and, during transmission it may often be found desirable to have the plane of the wires tilted away from the earth and towards the direction in which the beam of energy is to be propagated."

The last passage which I have read, teaches again that radiation is predominantly in the plane of the wires and along the bisector of the angle formed by the wires, and if, as the passage indicates, it is desired to secure radiation at an angle to the horizontal, the patent teaches, in the pas- [fol. 318] sage I have just read, that one should tilt the whole structure so that the plane of the wires will no longer be in the horizontal but will be titled so that the structure will point in the desired direction. That is, that the radiation in the plane of the wires will then be not horizontal but at the desired angle.

Q. 395. Now, with reference to this same subject matter and Mr. Hogan's treatment thereof in his direct examination, I will call your attention to Mr. Hogan's statement in

answer to Q. 71 (R. p. 177), which is, "With a V arrangement of that kind, the principal radiation of a pair of wires then takes place bidirectionally along the line of the bisector and principally in the plane of the wires." Was Mr. Hogan's understanding of the patent consistent with these passages that you have just read?

A. Yes, sir, that states clearly what the patent teaches.

Q. 396. Again, in answer to Q. 72 (R. p. 178), Mr. Hogan stated with respect to this Carter patent on this subject, "Carter's rule correlating the angle represented by alpha in Figs. 2A and 2B of the third Carter patent, correlating that angle with the wave length used, and with the length of the wire, taught how this principal radiation from the long diverging wire standing wave antenna could be concentrated not only in the plane of the wires, as occurred with the Lindenblad arrangement, but also still more effectively into a bidirective beam within that plane." Is that understanding of Mr. Hogan's as there expressed consistent with the statement in the patent?

A. Yes, sir, it is.

Q. 397. Finally, in answer to Q. 74 (R. p. 182), still in Mr. Hogan's direct examination, and referring to the Carter [fol. 319] third patent in suit, he stated, "Any one of these double V arrangements, that of Fig. 11, that of Fig. 5, or that of the model, has generally the radiation pattern in the horizontal plane which is shown by Fig. 6 of the patent. That is to say, all of them give primarily unidirective radiation along the bisector line." Is that statement of Mr. Hogan's consistent or inconsistent with the passages that you have read from the patent?

A. It is consistent with the passages which I have read.

Q. 398. Now, Mr. Kelley, do you know of any public statement made by the patentee, P. S. Carter, subsequent to the date of application for the third Carter patent in suit, wherein he stated contrary to the statements contained in the patent in suit that you have just referred to, as well as contrary to the testimony of Mr. Hogan that you have just referred to, that in both theory and practice horizontal radiation from a V antenna is zero?

A. Yes, sir, I have here a patent issued to Mr. Carter, No. 2,027,020, the filing date of which is September 15, 1932, and the issue date of which is January 7, 1936. In this patent, on page 1, line 3, he states: "In my United States patent No. 1,974,387," that is, the third Carter patent in this suit,

"granted September 18, 1934, there is described a V type antenna arrangement which is adapted to radiate energy directively. This arrangement comprises a pair of linear conductors which are long relative to the length of the communication wave and disposed at an angle in such a manner that when energized radiation occurs principally along the bisector of the angle." This passage refers to the third [fol. 320] Carter patent in suit and reiterates the teachings of the third Carter patent in suit, namely, that radiation will be predominantly in the plane of the wires.

However, on page 2 of this same recent Carter patent, line 30, it states, "In both theory and practice it has been found that the reflections from the ground are such as to always result in zero radiation horizontally at the usual communication distances from any short wave antenna. It has also been found that radiation at angles in the neighborhood of 10 degrees to the horizontal is most effective at a distant receiver." This latter statement is contrary to the teaching of the third Carter patent.

Q. 399. Does the defendant follow the teachings of the third Carter patent in its commercial antenna relative to the radiation being in the plane of the wires?

A. No, sir, it does not.

Q. 400. Is the statement which you have just read from the subsequently issued Carter patent correct with respect to the direction of propagation of waves in defendant's antenna?

A. Yes, substantially so.

Mr. Darby: I offer this Carter patent in evidence, No. 2,027,020, granted January 7, 1936, on an application filed 15/9/32, and I might remind your Honor that that application was filed subsequent to the stipulated date of erection of defendant's antenna.

(Marked Defendant's Exhibit U in evidence.)

Q. 401. Can you illustrate on Defendant's Exhibit T the significance of this matter of direction of radiation relative [fol. 321] to the plane of the wires in so far as it affects defendant's commercial installation?

A. Yes, sir. The lower left hand figure shows the radiation diagram which would be obtained in accordance with

the teaching of the third Carter patent. This diagram is purely theoretical, that is, the radiation diagram shown here is from a pair of wires formed in a V entirely removed from the earth.

As I recall, Mr. Hogan stated in his testimony that by departing from the angle specified by Carter by a small amount that defendant thereby sacrificed some of the benefit to be obtained by using the angle specified by Carter. In so stating he was, of course, following the teaching of the third Carter patent, namely, that the all-important thing is the radiation from a pair of wires in free space.

The corresponding radiation pattern from a pair of wires in free space, using the angle actually used by defendant in this No. 2 antenna, it would literally be true that radiation is the direction in which the third Carter patent teaches would be less, but defendant is not relying on this theoretical radiation because any antenna structure must be built with some relation to the ground; and defendant makes use of that relation to the ground to obtain the real radiation pattern which is shown in the upper right hand figure and will be seen to be inclined to the horizontal, the wires in defendant's No. 2 antenna being in a horizontal plane, the radiation actually obtained is inclined at an angle to the horizontal, and no radiation occurs in the horizontal at all.

And furthermore, referring now to what would happen [fol. 322] had the angle specified by Carter been used and the antenna constructed a similar distance above the earth, the lower right hand diagram shows what would have resulted due to ground reflection. And it is seen by comparing the two right hand figures that instead of sacrificing any real radiation by virtue of using a different angle, a different angle is used deliberately in order to gain more radiation in the direction in which it actually goes out. That is, the lobe on the upper right hand diagram representing what defendant obtained by departing from the third Carter patent teaching is greater than would have been obtained with ground reflection and all contained in the antenna arranged using the angle specified by Carter.

Q. 402. And what have you to say as to the angle of predominant radiation to the horizontal as in Defendant's antenna No. 2 relative to the angle specified in the subsequently issued Carter patent now in evidence as Defendant's Exhibit U?

A. It is the same angle, namely, 10 degrees with the horizontal.

Q. 403. Will you state whether or not your foregoing explanation and comparison is equally applicable to defendant's antenna No. 8, the chart of which is in evidence as Defendant's Exhibit S?

A. Yes, sir, the same explanation applies, and the figures are in the same relative position as on the previous exhibit.

In this case, and I believe the No. 8 antenna was referred to specifically by Mr. Hogan, he stated that by departing from the angle specified by Carter, namely, 50 degrees for this particular length of wire resulted in obtaining 95 per [fol. 323] cent of the benefit to be derived by using the third Carter patent. Now, that would be true on an entirely theoretical basis, namely, where one does not consider the ground at all, in other words, where one only considers the left hand diagrams. And your Honor will see that this upper left hand diagram is one theoretically obtained in defendant's No. 8 antenna, and by comparing it with the theoretical radiation diagram obtained, had the angle specified by the third Carter patent, 50 degrees, been used, it is clear that defendant's theoretical radiation pattern would be somewhat shorter and also somewhat fatter than the one obtained by the angle of 50 per cent in the third Carter patent. As a matter of fact, however, when this antenna is erected above ground, the result obtained by defendant departing from the angle specified by Carter of 50 degrees and using another angle, namely, 45 degrees, is that something like 8 per cent more radiation is obtained than could be obtained with using the angle of 50 per cent, namely, by an apparent sacrifice in the theoretical radiation defendant departs from the teaching of the third Carter patent and obtains 108 per cent of the radiation that could be obtained had the third Carter patent teaching been followed.

Q. 404. In all of the results the left hand charts on Defendant's Exhibits S and T, is the pattern as there shown, the pattern which would be obtained if radiation occurred, predominantly or mainly in the plane of the wires?

A. Yes, in accordance with the teaching of the third Carter patent.

Q. 405. In view of the foregoing, will you state whether [fol. 324] or not in your opinion the defendant's antennas

operate on the same or on a different principle from that taught by the third Carter patent in suit?

A. Defendant's antennæ operate on a different principle from that taught by the third Carter patent in suit.

Q. 406. Will you state whether or not defendant's antennas function the same or different from the functioning of the antennas as taught by the third Carter patent in suit?

A. They function differently, because they take into account this ground reflection.

Q. 407. You mean what takes into account?

A. They take into account, so that the ultimate result is better by departing from the third Carter patent teaching.

Q. 408. When you say "they" in your last answer you mean the defendant's antennas?

A. Yes, I mean the defendant's antennas.

Q. 409. Now, with reference to the results, would you say that the results obtained by defendant's antennas are the same as or different from the results obtained according to the teachings of the third Carter patent in suit?

A. They are different from the results obtained by the teaching of the third Carter patent.

Q. 410. Now I want to direct your attention to this angle alpha and the Carter formulæ for determining it. First turn your attention to the formulæ appearing at line 60 and line 70 of page 2 of the Carter patent, and will you state just what is the difference between the two formulæ and what they represent?

A. The two formulæ represent the variation in field strength or radiation in going around a wire of an electrical [fol. 325] length which is a whole number of half wave lengths long by means of which the radiation diagram having these lobes of which I have already spoken may be plotted, that is, that these formulæ enable one to plot out the radiation diagram of the field strength for conductors having standing waves on them and which are an integral number, a whole number of half wave lengths long.

The first formula is used when the number of half wave lengths in the length of wire is an odd number, and the second formula is used when the number of half wave lengths in the conductor is an even number.

Q. 411. Then is it or is it not correct that both formulæ are used as presented by this patent for determining the angle alpha?

A. Yes, sir, because by taking these formulæ and using them in the way they are intended to be used, namely, to show how the radiation varies as one goes around in a circle about the wire, and when so used show that in a certain direction radiation is much greater than it is in other directions, this is indicated by the lobes or ears that one obtains by plotting this formula.

Q. 412. From your study of the art prior to the Carter patent in suit was that formula novel at the time of application for this third Carter patent?

A. Not at all.

Mr. Darby: I offer in evidence a folder containing the following publications: M. Abraham's article of 1898 in Annalen der Physik und Chemie, with translation; M. Abraham's article in Physikalische Zeitschrift of March 2, 1901, with translation; Bergmann's article of 1927, in Annalen [fol. 326] der Physik; article by Bontch-Broojevitch, 1926, in Annalen der Physik, with translation.

(Marked Defendant's Exhibit V in evidence.)

Q. 414. Will you proceed to point out this formula and discuss the Abraham articles, first two Abraham articles, with reference to this?

A. Referring first of all to Annalen Der Physik, 1898, Abraham article, I wish first to call attention, referring to page 8 of the translation, to point out the two formulæ which occur on page 2, at lines 60 and 70 of the third Carter patent in suit.

On page 8, or rather the last sentence on page 7:

"Therefore the radiation of the intensity of radiation along a meridian is expressed by the absolute magnitude of the function."

And then appears an equation:

"which as a first approximation is proportional to the cosines squared by the expression pi N over 2 times cosine Phi divided by sine squared Phi for the odd numbered, and is proportional to sine square of the expression pi N over 2 times cosine Phi divided by sine square Phi for the even numbered periods."

The last two formulæ which I have just read are the corresponding power formulæ from which the field strength

formula came by merely omitting the square in the terms, that is, cosine squared is cosine and the sine squared is sine.

It is very common practice in referring to radiation patterns and formulæ connecting them, sometimes to refer to [fol. 327] what is called the field strength, and other times to refer to the power. The reason one is the square and the other, that is the power diagram is the square of the field strength diagram, or is proportional to it, is that the power is derived by multiplying the field strength, the magnetic field strength by the electric field strength, which, in a wave in free space, are equal, and by neglecting units and merely stating this a proportionality, it is common to use either the term where the square occurs or the other term where the square does not occur, almost interchangeably. It is well known when you put the square in you mean the power and when you don't put it in, you mean the field strength, but they both teach the same thing; there is no confusion there.

Q. 415 Is it or is it not a fact that any engineer in the art with a formula stated in either the power or the field strength knows the other?

A. These formulæ are well known, so there would be no confusion whatever. By comparing these two formulæ with the corresponding formulæ in the third Carter patent on page 2, line 60 and line 70, and omitting the square for the reason I have given, the formulæ are identical with one other insignificant exception, namely, that the symbol used for the angle in 1898 Abraham article is Phi, whereas in the third Carter patent it is another Greek letter, Theta.

Q. 416. On what page of the original German article are these two formulæ that you have referred to on page 8 of the translation? Is it 471?

A. Yes, sir, these formulæ to which I have referred are the two formulæ occurring near the top of page 471.

[fol. 328] Q. 418. I get confused in my own mind which is power and which is field strength. Is it power or field strength that is given by this formulæ of Abraham's?

A. The power formula is the one given in the article by Abraham.

Q. 419. Will you please refer to any other Abraham article which you have which shows the same formula for the field strength?

A. Yes, sir, I have. And before going to that I might say that this first article to which I have been referring,

namely the 1898 article of Abraham, is a rather long article and highly mathematical. It treats of the problem in an extremely rigorous and fundamental way. He considers instead of a wire to begin with, a long wire to begin with, he considers a rather peculiar shaped arrangement or conductor for the antenna. It is known by the mathematical name of ellipsoid of revolution. It is actually egg-shaped. He does this so he can apply the Maxwell equations for dynamic equilibrium, and in working out the result which I have referred to, these formulæ for the radiation pattern, he does so by assuming this egg-shaped arrangement to be excited in some way so that it will produce natural oscillations, that it will vibrate electrically, so to speak, in various harmonics.

After going through a very abstruse treatment of the problem. which frankly at points were confusing to me, the problem being handled in an extremely abstruse mathematical way, he makes clear, however, what progress he is making, so that one knows what he means when he gets to the end, namely, he solves this problem, first, in a general way, then he discovers that there are conditions which he must fulfill in order to obtain the correct solution, but which [fol. 329] necessitates his making certain approximations. These approximations are followed successively through the article so that eventually he winds up not with an egg-shaped figure, this ellipsoid of revolution, but with an elongated conductor, which is the same thing as a long linear conductor; in other words, a straight wire, and the formulæ which he gives apply to the radiation pattern from the straight wire, the formulæ as I have already indicated being two in number one referring to the case when the conductor is an exact even number of half wave lengths long, and the other when the conductor is an exact odd number of half wave lengths long.

Then proceeding to the 1901 Abraham article, that is, the one in Physikalische Zeitschrift, 2nd of March, 1901, this article again teaches of a similar problem, but in this case, he makes certain assumptions which are generally made, and have been generally made certainly ever since his day by those skilled in the art in deriving the formula for the radiation patterns obtainable from conductors an integral number of half wave lengths long. In other words, he assumes here not this egg-shaped antenna, as in the 1898 article, but

he assumes at the outset a straight wire on which current is distributed sinusoidally throughout the length of the wire.

Referring to page 5 of this Abraham article, the 1901 article, referring to Fig. 2, and beginning at the top of this page, page 5 of the translation, he states:

"A wire EF (Fig. 2) of length 1 rises vertically upwards [fol. 330] from the earth. The earth is to be considered a perfect mirror for electric waves. The earth point E is a node of electric potential. The wire is now reflected with respect to the earth's surface and the potential distribution is chosen in such a manner that the opposite potentials are prescribed by two corresponding reflected points, one on either side, thus is the electro-magnetic field of the wire EF above the earth identical with that of the wire FL′ of length 21 oscillating in free space."

What he means by that is that he is now considering a wire vertical and extending upwardly from the surface of the earth, and also that the earth's surface is a perfect mirror for electric waves, and that being so that the portion of the wire above the earth is reflected in the earth, so that it has an image of its own length, having the same current distribution, but having potentials which are of instantaneous opposite polarity.

Q. 422. Is that the same image or mirror that is referred to in the passage that I read to you with respect to the second Lindenblad patent?

A. Yes, he was referring to the same thing. And, as a consequence of this, Abraham takes the wire and its image as a wire twice as long off in free space, and neglects the ground entirely from then on. This results in the harmonics generated on the wire being the odd numbered harmonics. That is, in this article, the number of the half wave lengths in the length of wire that he is considering will be an odd number. Then he proceeds, assuming the current distribution that I have already referred to, that is, standing waves and sinusoidally distributed along the wire, and derives [fol. 331] the equations beginning on page 5, at the bottom of the page, and continuing on page 6, and also on page 7, until finally, on page 8, the formula is given, just below the middle of page 8,—namely cosine of the expression pi n over 2 cosine theta sub zero divided by sine theta sub zero, for the field strength radiation diagram for the long linear con-

ductor given in the third Carter patent on page 2, line 60. And in conjunction with this formula, referring still to page 8, the first full paragraph on that page.

"This electric magnetic field corresponds to a spherical wave, which spreads out rapidly from the middle point of the wire. We consider a sphere as r zero equals constant, and construct circles of longitude and latitude where we regard as the poles the points at which the extensions of the wire axis pierce the sphere. The magnetic force is everywhere in the direction of the circles of latitude, the electric force being oriented in the direction of the meridians. Both are perpendicular to the direction of propagation of the wave. The intensities of the forces vary with the latitude theta sub zero, according to the equation I have just referred to. Accordingly, for the fundamental oscillation (n equals 1) the amplitudes reach their maximum value at the equator (theta sub zero equals pi over 2)."

Pi over 2 is simply 90 degrees expressed in radians, that is, at right angles to the wire with the length of the wire for a half wave length long. Then at right angles to the wire will occur maximum radiation.

[fol. 332] I believe in the first Lindenblad patent, Fig. 1, there is shown a diagram corresponding to the half wave length radiator, and it will be seen the line, the vertical line between those lobes represents the direction of the wire, and the maximum radiation is seen to be in the direction at right angles to the wire.

"At the pole theta sub zero equals zero, the intensity is zero."

That is, lengthwise of the wire there is no radiation. That also is shown in Fig. 1 of the first Lindenblad patent to which I referred. This is universally true, of course, regardless of the length of the wire, there is no radiation lengthwise of the wire.

"For the fundamental oscillation the amplitude constantly diminishes from the equator to the poles. The harmonic oscillations, on the contrary, possess still other minima and maxima."

That is, when the length of the wire is not merely one-half wave length, but a plurality of half wave lengths, then, ac-

cording to the formula given here, the radiation pattern will be such that there will be many directions, corresponding, of course, to the number of half wave lengths in the wire, there will be many directions in which there will be maxima of radiation, in between which there will be zero radiation, and then again maxima radiations and so on, going around the wire.

By plotting out these formulae, it is observed that these maxima or lobes are not all of equal intensity, that is, the [fol. 333] length of the lobes is not the same in each case in going around the wire. That is, one wouldn't get a pattern looking like the arrangement of the petals of a daisy, but one gets a pattern in which the lobes nearest the wire, that is the first one you come to as you explore going around the wire, the nearest one you come to is always the largest lobe, and then, as is clearly shown by plotting these formulæ, the lobes are smaller and smaller and smaller, and then, again, they grow so that by the time one has reached the last lobe before coming along the length of the wire in the other direction, one will then obtain another large or principal lobe, and so on, around the wire.

Q. 423. Is that illustrated, the type of lobe you refer to, illustrated in Fig. 1b of the Carter patent in suit, the third Carter patent in suit?

A. Yes, sir, that figure, that is Fig. 1, represents such a diagram plotted using the Abraham formula when the wire is five wave lengths long. And as I have explained the principal lobes, that is the largest ones, which are apparent on expressing this equation in graphical form, correspond to the ones directed in the directions Y in Fig. 1b of the third Carter patent. The smaller lobes that I referred to, the ones not inclined so near to the wire, are the intermediate ones, so-called minor lobes.

Q. 424. Have you completed your consideration of this second Abraham article?

A. Except that I simply wanted to add that continuing where I left off, reading on page 8, namely, the last sentence on the page:

"The maxima lie in the latitude circles determined by [fol. 334] cosine theta equals plus or minus, M divided by N, when M is a whole odd number."

This merely states at what angles the indentations, that is, the angles at which zeros will occur between lobes as one goes around the wire.

Q. 425. In comparing the formulæ of the first Abraham article of 1898 with the formula given by the patent in suit, you called attention to the fact, I believe, that there was one difference, namely, that the angle in the patent in suit was referred to by the symbol theta, whereas the angle in the 1898 Abraham formula was called phi?

A. That is right.

Q. 426. What have you to say as to this respect in connection with the formula in the Abraham 1901 article relative to the formula shown in the patent in suit?

A. In the 1901 article Abraham uses the symbol theta to represent this angle just as Carter does in the formula shown at page 2 of the third Carter patent.

Q. 427. Is that likewise true with respect to the claims of the patent where the formula is included in the recitation?

A. Where these same formulæ are included, also apply.

Q. 428. Is or is it not the formula of Abraham identical in expression with the formula given by Carter?

A. Yes, sir, the formula occurring on page 2, lines 60 and 70.

Q. 429. Are his symbols identical or not?

A. Well, as I have indicated, in the 1898 article the symbol for the angle is referred to as phi, whereas in Carter's formula it is called theta. It is insignificant what you call it, but it so hapepns that in the 1901 article Abraham also calls it theta.

[fol. 335] Q. 430. In the 1901 article of Abraham, does he there express the formula in terms of field strength?

—. He there expresses the formula in terms of field strength, yes, sir.

Q. 431. Is it or is it not a fact that the Carter patent expresses the formula in terms of field strength?

A. The Carter patent expresses the formulæ here in field strength.

Q. 432. Are the formulæ of the Abraham article identical with or different from the formula of the Carter patent in suit in so far as their meaning is concerned?

A. The formulæ given in the Abraham articles and the formula given in the third Carter patent are not different

at all in so far as their meaning and significance are concerned.

Q. 433. Will you please refer to the empirical formula of the Carter patent in suit and state in what respect, if any, it differs from the other formula to which you have already referred?

A. I believe I can best answer that question by indicating in what manner this empirical equation is arrived at. I have already referred to the fact that when plotting the Abraham formula it is found that all of the lobes are not equal in extent; and that especially as the wires get longer and longer, the lobes inclined nearest to the wire are decidedly larger than any of the other lobes. In other words, it indicates that the application, the graphical representation of the Abraham formula, shows that a single wire excited in its harmonics is a decidedly directional radiator and that this directional characteristic is in the direction of these principal lobes, the ones I have mentioned being inclined nearest to the wire and the ones that I have stated as being [fol. 336] shown by plotting the Abraham formula. And since the greater part of the radiation from the single wire occurs in the direction of these principal lobes, that direction is, of course, given by the Abraham formula simply by plotting the angle and may be determined graphically in that manner.

It may also be obtained by mathematical operation of determining, in accordance with the principle of differential calculus, maximum values, and if it is done that way you would still have a graphical step to perform and the result would be the same anyway.

What is done in order to arrive at angle alpha, which is this angle where the Abraham formula has a maximum which is greater than the other maxima, in other words, where the Abraham formula has a large lobe in comparison with the smaller ones, that particular angle is the angle alpha referred to in this third Carter patent, and in arriving at an empirical formula, one takes a wire one-half wave length, finds out the angle in which this maximum occurs with the Abraham formula and plots a point; then he takes two halves, three halves, four halves, and so on, in other words, every half wave length, and in each case determining from the Abraham formula at what angle this principal lobe of radiation takes place, and plots that result, namely, the

correlation between the length of the wire, since it is half a wave length, one, one and a half, and so on, plots that against the length of the wire, this angle, which Carter designates as alpha, and through this series of points draws a smooth curve, remembering, of course, that the formulæ apply only to discrete points.

[fol. 337] Q. 434. Is this angle that Carter designates as alpha in that instance the same as theta in the formula?

A. It is the same as a particular value of theta, namely, the value at which this maximum lobe occurs, the nearest one to the wires. Then the empirical formula comes from this, having drawn a curve, smooth curve, through these points, in other words, disregarding whether or not anything happens in between these points to which the formula doesn't apply, but merely drawing a smooth curve through these points, then by methods well known to engineers, deriving a curve, an equation, rather, which fits the curve as near as possible practically. And the result of that is the empirical formula given on page 2, line 85.

Summarizing what I have said, this formula is an artificial equation, you might say, given to a curve drawn through the discrete points for the different lengths each of a number of half wave lengths at which the angle of theta is in the principal direction.

Q. 435. Is or is not the correctness of the empirical formula given on page 2, line 85, dependent upon the correctness of the curve illustrated in Fig. 12 of the Carter patent?

A. As near as I can tell, the curve in Fig. 12 of the Carter patent is the curve of the empirical equation. It is a simple plot of that equation, as near as I can tell.

Q. 436. Does or does not the accuracy of the curve illustrated in Fig. 12 of the third Carter patent in suit depend upon an assumption with respect to its accuracy between points representing half wave lengths?

A. It depends upon the assumption that the Abraham [fol. 338] formulæ, from which it is derived, are equally applicable at other lengths than an integral number of half wave lengths.

Q. 437. Have you made an enlargement of Fig. 12 of the Carter patent in suit on which you have likewise plotted the curve according to the Abraham formulæ?

A. Yes, I have.

Q. 438. I notice that there is a curve on there marked Bruce. For the present will you please ignore that? Describe what you have thus shown.

A. The curve labeled Carter angle followed by the empirical equation, which occurs on page 2, line 85 of the third Carter patent, is actually the curve of Fig. 12 of the third Carter patent.

The curve labeled Abraham angle was added by me to indicate the comparison between the curve obtained with the empirical formula of Carter and the actual curve obtained by plotting the Abraham angle.

By comparing the two curves it will be seen that the empirical curve fits rather well the curve for the Abraham angle above lengths of approximately two wave lengths, whereas, using that also as a rough dividing line for shorter lengths of wire, the curve showing the Abraham angle departs from the Carter empirical curve by the amount indicated.

Q. 439. And on which side lies accuracy, the Abraham formula or the empirical formula?

A. The Abraham angle, of course, is the one which is the proper one to use. The departure of Carter's curve merely indicates the extent to which the equation does not fit along that portion of the curve, the extent to which it does not fit the curve obtained by drawing through points [fol. 339] obtained by substituting in the Abraham formula, that is, the so-called Abraham angle curve.

Q. 440. As a matter of fact, does the empirical formula or the curve of Fig. 12 of the Carter patent correctly show what actually occurs with wires, radiating wires that are not exact multiples of half wave lengths?

A. It doesn't show exactly what the curve should be for lengths which are not exact multiples of a half wave length. All of this is based on the assumption that the length of the radiators is an integral number of half wave lengths and consequently one cannot go beyond the assumptions, and for that reason it is not true to say that this is accurate for points in between.

Q. 441. Would that be shown by what is referred to as radiation resistance curves?

A. Well, indirectly it would be shown by the radiation resistance curves.

Mr. Darby: I offer in evidence the enlarged Fig. 12.

(Marked Defendant's Exhibit W in evidence.)

Q. 442. Will you please refer to the subject of radiation resistance curve and its bearing on the matter under consideration? First let me ask you, are you familiar with the article of Carter, Hansell and Lindenblad in the Proceedings of the I. R. E. here in evidence as Plaintiff's Exhibit No. 20?

A. Yes, sir, I have read it.

Q. 443. Do you or do you not understand this article to constitute a more detailed description of the subject matter of the patents in suit?

[fol. 340] A. I understand this article to deal rather in detail with the subject matter of the patents in suit.

Q. 444. Is there any radiation resistance curve shown in this article purporting to represent antenna of the character referred to in the third Carter patent?

A. Yes, sir, on page 1803, Fig. 21. I might explain, first of all, I, having said previously but indirectly, radiation resistance shows up this difference, or, I will put it this way: The fact that the results of the Abraham formulæ are applicable only to wires an integral number of half wave lengths long, the reason for so stating is this, that the Abraham formulæ showing the radiation distribution or pattern about a long linear wire, those formulæ are used in order to determine the radiation resistance of the long linear wire.

The curve shown in Fig. 21 of the I. R. E. article, on page 1803, the upper curve is labeled "Radiation Resistance". The figure is entitled, "Radiation Resistance and Power Ratio of the Long Wire Radiator," that is, a single wire electrically long with standing waves on it. The radiation resistance curve is the upper curve, and it is shown as a smooth curve, that is, although it is curved, its curvature is always in the same direction. It is a smooth curve, and evidently was plotted from discrete points for which the radiation resistance was determined, those discrete points being for exact multiples of a half wave length and then, as in Fig. 12, referring to angle alpha in this figure, draw-

ing a smooth curve through those points and obtaining the result shown in Fig. 21 in the upper curve.

Q. 445. Will you refer in this connection—and we will [fol. 341] come back to this diagram—will you refer in this connection to the article of Bontch-Broojevitch that is in evidence for its bearing on this particular subject, referring particularly to page 438 of the original German, at page 9 of the translation?

A. Referring to page 15 of the translation, formula 29, given just below the middle of the page, corresponds to the formula 27 on page 1802 of the I. R. E. article. The only difference here is Bontch-Broojevitch includes a factor NI^2 before the brackets in equation 29, merely for the purpose of dividing up the power radiated in these half wave length oscillators, in which fashion he regards the long linear wire, half wave length oscillators M to N, and to divide it up in terms of how much power is radiated from each one of these.

In order to express this as radiation resistance, all that is necessary to do is divide both sides by NI^2, which is quite clear from the meaning of the formula. And when this is done, it is identical with equation 27 of the I. R. E. article that is on page 1802. In the brackets of equation 29 in Bontch-Broojevitch, on page 15 of the translation, the letter E designates what is known as Euler's constant, which is equal to .5772. In the equation 27 in the I. R. E. article, instead of writing E for this term, the actual value is given.

Following equation 29 of the Bontch-Broojevitch article, it says:

"Where CI, as before, is the integral cosine, the value of which is not far from zero. The following table gives the values of the resistance for the various values of n."

[fol. 342] Now, there follows a table in which the upper row or the successive numbers 1, 2, 3, 4, 5, 6, 7 and 8, and they are the values of n, that is, the number of half wave lengths in this linear radiator.

The second row gives the radiation of resistance due to each one of these half wave length oscillators; as the number increases, that is, you correlate the upper row with the corresponding value immediately below it. So that to convert this into the total radiation resistance of the whole radiator, one multiplies the lower figure by the upper one.

For example, where n equals 1 the radiation resistance is 72.5 ohms, one times 72.5. Where the number is 2 it is 2 times 47 or 94 ohms, for the whole radiator, and so on.

Plotting these values, one obtains discrete points, a point for each half wave length, and these points, with the exception of one, in which there appears to be an error at No. 7, all of the other points would fall on the radiation resistance curve shown in Fig. 1, on page 1803 of the I. R. E. article.

Q. 446. Now, have you had plotted a radiation resistance curve showing what departure, if any, from one taken on the half wave points would occur for antenna wires having radiators which are intermediate between half wave lengths in lengths?

A. Yes, I have.

Q. 449. Will you please produce the curve and describe it?

A. Yes. The radiation curve which I had computed shows what actually happens at intermediate points, that is, points which are not an integral number of half wave lengths long.

If a smooth curve is drawn through the radiation resistance points for the integral number of half wave lengths [fol. 343] long, then that curve would follow generally the top of impedance of the radiation resistance curve which I am now referring to.

It shows at once the error that one falls into in going beyond the assumptions upon which the original work was done, that is the Abraham formulæ, and radiation resistance equations derived from the Abraham formulæ applied only to half wave lengths—two radiators having an integral number of half wave lengths in length.

This curve which I am producing shows that the radiation resistance falls off to a substantial amount in between these values of half wave lengths, that is, the valleys along this curve represent the radiation resistance that would be obtained if a wire were an odd number of quarter wave lengths long, rather than an integral number of half wave lengths long.

Q. 451. And the quarter wave length would be the maximum deviation from intervals of half wave lengths?

A. Clearly, because if you go beyond a quarter wave length the distance in one direction, you are approaching the next half wave length point.

Mr. Darby: I offer the chart that the witness has referred to in evidence.

(Marked Defendant's Exhibit X in evidence.)

Q. 452. Now, I direct your attention to the fact set forth in the stipulation of defendant's antennæ, that with one exception, namely antenna No. 8, none of the radiating wires of defendant's antennæ are exactly an integral number of half wave lengths long, and I wish you would please develop for me the comparison between the radiation effected from [fol. 344] an antenna wire of eight wave lengths, which, therefore, is an integral number of half wave lengths, and as compared to that, a pattern radiated from a radiating wire of 7¾ wave lengths, which is not of an even number of half wave lengths, and is substantially the same as antenna No. 2 of the defendant, which is 7.74 wave lengths long.

A. In the case of both of these charts, the radiation pattern is shown for one side of the wire only, and is not shown for the other side of the wire, merely for convenience, because it is the same thing. That is, the lobe shown above the wire—the wire in this case extending in a horizontal direction, would be the same as the lobes below the wire, and would only be a duplication. That is true in the case of both of these charts.

These charts represent a field strength diagram, one of them for a linear wire eight wave lengths long with standing waves and hence, an integral number of half wave lengths long, since there would be 16 half wave lengths in the wire.

The other chart shows a field strength diagram for a wire which is close to the eight wave lengths long in length, departing only one-quarter of a wave length from it. This again shows a field strength diagram from such a wire.

The first thing to notice is that in the case of the eight wave length straight wire, the lobes shown to be connected by a straight line drawn across the figure, that is, if one laid a straight edge across the top of this figure, the lobes should all touch that line.

Q. 453. What does that mean?

A. That means, that the bearing of that is on the amount [fol. 345] of radiation going in these other directions, that is, in the directions of the so-called minor lobes.

Q. 454. Is that wasted radiation?

A. In many cases, it is wasted radiation.

Q. 455. Is it undesirable radiation?

A. It is undesirable radiation practically. That feature, namely, being able to lay a straight edge along all of the lobes so that it will touch them, is not true of the radiation diagram of the seven and three-quarters wave length straight wire; but, on the contrary, there is a decided departure from this so-called straight line rule. The key to this departure is in the dip that I previously pointed out in the radiation resistance curves which occur between each of the integral number of half wave lengths, that is, the valley in this radiation resistance curve that I have produced occurs at a quarter wave length spacing from the nearest half wave length distance.

The significance is this: That the radiation, I am now referring to the radiation of the seven and three quarters wave length straight wire, that the radiation in the undesired direction, that is, in the direction of the minor lobes, is substantially less in proportion compared with the radiation in the desired or maximum direction than it is in the case of the radiation from a wire eight wave lengths long, where these lobes constitute a considerably greater radiated amount of energy in comparison with the long lobe or the principal lobe. The result of this is that better directivity results by departing from an integral number of half wave lengths, and going to an odd number of quarter wave lengths, which will place you in between an integral number of half wave lengths for the length of your radiator.

[fol. 346] It is interesting in a pictorial sort of way why this happens. After all, when standing waves are formed on a linear oscillator, it is merely another way of saying that traveling waves occur simultaneously in two directions, and by virtue of the fact that they travel with the same frequency, that they have the same frequency and travel with the same speed in opposite directions, one has the standing wave. One can consider the radiation pattern from each of the traveling waves taken separately, and when one does so, one finds that there is a radiation pattern somewhat similar to the radiation patterns which one gets using the Abraham formula, with the exception that there occur only two principal lobes or principal lobes generally in the direction in which the wave travels, because that is the way in which you radiate most favorably, and rather a small

amount in other directions, and particularly in the opposite direction nil.

That occurs, if I may use my fingers to represent the principal radiation for the traveling wave going from right to left, these principal lobes will occur so (demonstrating), and going from left to right, will appear so (demonstrating). And the two together give the diagram that we have referred to in connection with Abraham. However, in combining the effects of the two traveling waves, the minor lobes associated with these major lobes add and subtract depending on the phasing and spacing, so that it happens that when the wire is an integral number of half wave lengths long, they add up to produce this pattern which in an integral number of half wave lengths long, and has the straight line characteristic that I mentioned in connection [fol. 347] with the lobes. On the other hand, the manner in which the side lobes add up when it is an odd quarter number of wave lengths long, is such that there is not as good addition of the minor lobes in between the major lobes, and consequently radiation in the undesired direction is thereby reduced.

And this explains also why it is a mistake in this radiation curve to go ahead and assume that because the points calculated in accordance with the Abraham formula used as a basis and which apply to the radiators of an integral number of half wave lengths long, it shows that it is a mistake to assume that a smooth curve drawn through that will also go by interpolation of that curve the radiation resistance of any length of wire having lengths of intermediate values then an integral number of half wave lengths.

Q. 453. Is it or is it not a fact that all the defendant's antenna except antenna No. 8 are electrically substantially a quarter wave length longer than a plurality of half wave lengths?

A. All the defendant's antenna with the exception of No. 8 departs from a length which is an integral number of half waves lengths, and they are, for the most part, very close to an odd quarter of wave lengths in length.

Mr. Darby: I offer in evidence the two charts referred to by the witness, the first, a radiation of eight wave lengths, straight wire.

(Marked Defendant's Exhibit Y in evidence.)

Mr. Darby: Secondly, the radiation of chart 7¾ wave lengths, straight wire.

[fol. 348] (Marked Defendant's Exhibit Z in evidence.)

Mr. Darby: For that purpose, if your Honor pleases, I now offer in evidence the following folder containing:

Bethenod French patent No. 596,737.
Bethenod French patent No. 625,293.
Braun patent No. 763,345.
Brown British patent No. 1449 of 1899.
Heising United States patent No. 1,562,961.
Levy French patent No. 593,570.
Levy French patent addition No. 30,798.

An article by Benjamin S. Melton in the Q. S. T. of August, 1926.

Pages 156 and 157 of a book by John Mills, "Radio Communication, Theory and Methods," published by the McGraw-Hill Publishing Company in 1917.

Reuthe patent No. 1,314,095 of 1919, and
Takagishi Japanese patent No. 70,583, of 1926.

(Marked Defendant's Exhibit AA in evidence.)

Q. 456. Will you refer to the French patent to Bethenod, 596,737, and the translation thereof, and first state what the patent is directed to by its title?

A. This patent to Bethenod is entitled "System of Aerials for the Transmission of Short Wave Wireless Telegraph Signals."

He discloses a short wave directional system, antenna system, consisting of linear conductors, a plurality of half wave lengths long, fed from the opposite poles of a high [fol. 349] frequency generator so that standing waves are produced on the linear conductors.

These linear conductors may be arranged parallel to each other or inclined at an angle to each other, that is, in the form of a V.

In the specification, referring to Fig. 1—and by the specification I mean the translation—on the first page, after describing generally what is shown in the figure pictorially he goes on in the last paragraph on that page to state, "A similar arrangement, that is, as is shown in Fig. 1, may be provided for the emission of short waves and in that case

the antenna thus constituted may be operated at the harmonics.'' By being operated at the harmonics he means with standing waves such that the electrical length of these parallel wires constitutes a plurality of half wave lengths. That is what is meant by the antenna being operated at its harmonics.

Continuing, ''However, in accordance with the arrangement forming the object of the present invention, it is important that the high poles be retained if it is desired that the antenna function in accordance with its fundamental wave. As a matter of fact, calculations and experiments show that with short waves the higher the elevation of the counter-poise above the ground, the greater the advantages that may be derived therefrom. This consideration will lead one to the arrangement shown in Fig. 1 to exemplify the invention.'' Referring to Fig. 1 of the patent, the two radiators composed of parallel wires are indicated by the numerals 2 and 3 and they are fed from a high frequency source shown by a box labeled HF, the opposite poles of the [fol. 350] source being connected through the wires 5 and 6, one to each of the linear radiators. These radiators, as stated in the passage which I read, are excited at a harmonic, which means that the conductors forming the radiators are electrically long and will consist of a length of a plurality of half wave lengths.

Referring to the last page of the translation of the specification, the first full paragraph on that page, it says, ''Obviously numerous other variants are possible, particularly the two networks 2 and 3 of Fig. 1 may be arranged vertically or even inclined not only with respect to the ground but also with respect to one another so as to obtain directional effects either in the horizontal plane or in the vertical plane or in both planes.

''Furthermore, as is well known, the antenna may, in all cases be, if necessary, excited at its harmonics.''

The last page which I read refers to Fig. 1 and says that these radiators which are shown parallel to each other in Fig. 1 and extending in a horizontal direction may be arranged still parallel to one another, but extending in a vertical direction, or they may form an angle with each other, in other words, they may form a V. And that being so, and exciting the wires at harmonics, in other words, having a

plurality of half wave lengths, that directional effects in the horizontal plane, in the vertical plane, and even in both planes, may be obtained by using the wires in these various arrangements. It is understood, of course, that proper spacing must be taken into consideration.

[fol. 351] I want to explain that in these groups of wires, in each of the radiators, is shown several wires forming the radiator. I believe Mr. Hogan in referring to the third Carter patent, Fig. 4, for example, where two wires are shown, two wires on each side of the V, that these two wires, although there are two wires shown, that Fig. 4 really represents the equivalent of one single wire V. And also in connection with Fig. 11, where each side of each of the two V's shown there constitutes four wires on a side was said to be equivalent to two single Vs in tandem, that is, one behind the other. Also in connection with the networks, or wires, rather, of Fig. 1 of the Bethenod patent, these may be looked on as equivalent to a single wire radiator in each case. This arrangement, electrically long wires fed from the opposite poles of the high frequency generator, excited in phase opposition, is equivalent to Fig. 3 of the first Lindenblad patent in suit.

Q. 460. Now will you compare the disclosure with the disclosure of the second Lindenblad patent in suit No. 1,927,522?

A. Assuming that the second Lindenblad patent is for a standing wave antenna, in other words, assuming that Fig. 2 represents the second Lindenblad disclosure or invention, then when the networks of Fig. 1 of the Bethenod patent are inclined to each other, the result will be equivalent to Fig. 2 of the second Lindenblad patent.

Q. 461. Now will you compare the disclosure of the Bethenod patent with that of the third Carter patent?

A. In Fig. 1, with the wires inclined to each other, that is equivalent to the third Carter patent in suit.

[fol. 352] Q. 462. With the V antenna?

A. With the V antenna.

Q. 463. Now will you please take up the second Bethenod patent, 625,293 and its translation?

A. This Bethenod patent 625,293 also relates to a short wave directional antenna, and in that case he shows a tilted wire or inclined wire antenna on which standing waves are produced, which, in conjunction with its negative image,

its image in the ground, constitutes a V antenna in which the standing waves produced on the tilted wire are accompanied by standing waves of opposite instantaneous polarity on the image in the ground so as to produce a directional radiation.

And that this angle between the wire and the ground, which forms the bisector of the angle between the wire and its image, may form any angle from zero degrees to 90 degrees.

Referring to the translation of the specification, the first sentence states:

"The object of the present invention is an antenna arrangement which is particularly advantageous in communicating by means of short waves."

The last full sentence on the first page of the translation:

"The portion BC," referring to the only figure, "the portion BC of the antenna may form an angle D of any value from zero to 90 degrees with the horizontal."

And then the first full sentence on the second page of the translation:

[fol. 353] "In order to obtain the greatest radiation efficiency for the antenna, the length of BC should preferably be equal to a whole number of half wave lengths."

Q. 464. How does that recommendation compare with the recommendation of the third Carter patent in suit, prior to the amendment of August, 1934?

A. It is exactly the same recommendation in so many words, that the length of the radiating portion should be equal to a whole number of half wave lengths.

Referring to the figure, it is important to consider the cooperation of the radiating wire BC with its image in the ground. I have already read from the 1901 article of Abraham in which it will be recalled he first considers an antenna located above the earth's surface. Then he stated that the earth's surface will be considered as a perfect reflector for electric waves, and that when so considered, the radiator above the ground is perfectly reflected in the ground and has an image and this image is of the same

length, has the same current distribution and has opposite instantaneous polarity with respect to the portion above the ground.

And then he considered that whole antenna system, that is the wire above the ground and the image in the ground, as one whole unit twice the length of the wire above the ground, with ground removed from all consideration thereafter.

This is typical of the manner in which those skilled in the art analyzed the radiation from an antenna erected above the ground. It is recognized, of course, that actually one never finds a perfect ground. Nevertheless, in consid- [fol. 354] ering antennae in relation to the ground, it has been the custom of those skilled in the art first to assume that it is a perfect ground and whatever resulting radiation occurs, as it does, from an antenna in cooperation with its image in a perfect ground is exactly the same for a distant point as if the two existed in the relation of the reflected image of the real antenna, the reflected image being the negative image, that is, having opposite polarity with respect to the real antenna, and that the radiation at distant points may be determined just as though no ground were present at all, and that the two structures actually existed.

In this patent to Bethenod, this teaching is very clear to one skilled in the art, namely that a radiating wire BC electrically long and with standing waves excited on it, throughout its length, being a plurality of wave lengths long, in radiating, may be considered as being accompanied by another radiator forming the same angle D but on the other side, that is, so far as position is concerned, it is its optical image in the ground, hence a V, and that that image will radiate energy of opposite polarity from the radiator BC, and that the two will combine, just as if two wires were present, two wires of standing waves of opposite polarity and inclined to each other.

Bethenod states that the angle D, that is the angle formed by the wire and its image in the ground, may be from zero degrees to 90 degrees.

Q. 469. Will you please compare the disclosure of the Bethenod patent No. 625,293 with the second Lindenblad patent?

A. Assuming that the second Lindenblad patent is what is shown in Fig. 2, and that it is for a standing wave an-

[fol. 355] tenna system, then when the angle D is some other angle than zero degrees, the antenna system shown by Bethenod, the radiator BC co-operating with the negative image in the ground, will then be equal to Fig. 2 of the Lindenblad patent. In fact, in the second Lindenblad patent on page 2, line 93, it states:

"In connection with Figures 3 and 5, the desired radiation will, of course, take place in the direction of the axis of the transmission line 24 and the diverging conductors. Taken from another point of view, we can consider merely the upper half of Figures 3 and 5 as being in a vertical plane with its image in the ground;".

And this means exactly what I have explained in connection with Bethenod and the image of the radiator BC in the ground, in other words, that Lindenblad, after describing the figures 1, 2, 3 and 5 as being excited in phase opposition and having two sides to the circuit, in the passage which I read to you, considers that one side of that circuit is entirely replaced by the image of the remaining in the ground.

And to finish the sentence that I read:

"we will then have two serially connected conductors (conductor 26 and the upper antenna leading to transmission line 24 in figure 3)."

Q. 470. Does that same comparison apply to the third Carter patent?

A. Yes, sir, the same comparison would apply to the third Carter patent.

Q. 471. Will you please refer to Levy French patent of [fol. 356] addition, No. 30,798, and its translation?

A. In Fig. 1 of this patent, to Levy, there is shown an antenna system, consisting of a pair of wires 1 and 2, pair of antenna wires, 1 and 2, excited in phase opposition from a generator 11. And referring to that figure, on the first page of the translation, the second full paragraph:

"In the first place, it is desirable to point out that it is possible instead of adopting the arrangements described in the main patent, to conceive of different variations which may offer advantages in certain cases, particularly where it is desired to radiate energy in a given direction."

That is, this is a short wave directional antenna system,

"For example" (continuing), "wires 1 and 2 in the arrangement shown in Fig. 1 of the main patent, may, instead of being parallel to the same direction, form between themselves any angle and particularly they may be perpendicular. Fig. 1 of the accompanying shows an antenna whose radiators 1 and 2, situated in the same horizontal plane, form between themselves an angle of less than 180 degrees (the same reference numbers have been used as in the main patent to designate corresponding parts)."

In other words, Fig. 1 of this Levy patent calls for a V antenna in which the wires of the V are in a horizontal plane and which are fed from the opposite poles of a high frequency source and therefore in phase opposition.

[fol. 357] Q. 472. Would traveling waves or standing waves form on the radiating antenna wires of this Levy patent?

A. The antenna wires are open ended, therefore, there would be standing waves formed on them of opposite instantaneous polarity, of course, by virtue of the opposite polarity of the feeding.

Q. 473. Will you refer to the original French, that is, Levy patent 593,570, and point out its pertinence?

A. This patent to Levy is of especial interest because he sets forth in the specification much that is of practical benefit in connection with the transmission of short wave signals by the use of horizontally polarized waves. Defendant's antennae are all of this type, that is, horizontally polarized.

Referring to the first sentence at the beginning of page 2 of the translation, it states:

"Further, the invention also contemplates the use of sending antennæ radiating horizontal electric field instead of a vertical electric field, with the purpose of obtaining a great directional effect and smaller losses during propagation.

"An extremely important point, necessitating the use of a horizontal electric field, is that long distance transmission of short waves seems to be effected by reflection on the Heaviside layer."

That is one of the reasons why it is desirable, in fact necessary, in order to communicate at great distances on short

waves to incline the radiation at an angle to the horizontal [fol. 358] in order to make use of the reflection from the ionized strata in the upper atmosphere.

Continuing, the third full paragraph:

"Horizontal antennæ have already been used, but these antennæ have been applied for long wave lengths and relatively very close to the ground. The invention envisages, on the contrary, horizontal antennæ for the transmission of short waves and placed at a height representing an important fraction of the wave length transmitted (one-quarter wave length, for example). Thanks to this height and to the horizontal character of the electric field, the losses in the neighborhood of the electric antenna are greatly reduced."

This instruction as to the range of height at which the antenna should be placed corresponds approximately with what defendant practices. The tabulated data, at any rate, the wires being generally 80 feet above the ground, and the wave lengths of such order that this order of distance of a quarter wave length, or thereabouts, is approximately adhered to.

Continuing at the middle of page 2:

"It is extremely important to raise the horizontal antennæ to a suitable height, greater than one-eighth of the wave length transmitted. In effect, the conductive ground effect is to give an image of the antenna. If the antenna is close to the ground this image, which radiates an inverse field to the one radiated by the antenna, partially neutralizes the effect at a distance from the antenna. This objection- [fol. 359] able feature is avoided when the height of the horizontal antenna is comprised between one-eighth of the wave length lambda and five-eighths lambda. In this case, in effect, the radiations of the image and of the antenna combine. It is easy to figure also the effects of inclination on the horizontal plane of the maximum energy in the vertical plane of maximum radiation, effects which are produced owing to the combination at a distance of and the radiation of the antenna and of its image whose currents are out of phase by a quantity which depends upon the height at which the horizontal antenna is arranged."

The passage which I just finished reading is another explanation, I will put it in different words, of the difference

between the left hand figures and the right hand figures of the Exhibits S and T.

Q. 475. If I may interrupt there, Mr. Kelley, are all of defendant's antennas more than an eighth of a wave length above the ground?

A. Yes, sir, in every case well above an eighth of a wave length.

Q. 477. Will you proceed with the consideration of the Levy patent?

A. On page 4 there is a summary in which various items are summarized with serial numbers. The first item of the summary is the transmission of horizontal electric field waves to favor the reflection without loss on the Heaviside layer and on the ground and the propagation through space.

Item 4A. The single propagation antenna consists of two horizontal wires or two networks connected respectively to [fol. 360] the two poles of a high frequency generator. This item means that the radiating wires are excited in phase opposition.

Reference is also included in here to networks which are of no interest in the reference to the patents in suit, the arrangement shown in Fig. 1 of the patent of addition being the particular one.

4B. The antenna is placed at a height comprised between lambda over 8 and 5 lambda over 8, lambda equalling wave length transmitted, that is, the antenna is placed between an eighth of a wave length above ground and five-eighths of a wave length above ground.

4C. The two poles of the generator are connected respectively to each of the networks, that is, excited in phase opposition.

And 4D. Each of the networks is approximately a quarter wave length long.

And on page 5, 4J, the application of these devices for transmission and reception is envisaged particularly with short waves of less than a thousand meter wave length, that is, that this patent calls for short wave transmission.

Q. 478. Referring to Fig. 1 of this patent where there appear to be three radiating wires, and in the French patent of addition, in Fig. 3, there appear to be three in each of the legs of the V. Is this type of antenna, a number of parallel wires, the same or different from the type shown in the first Bethenod patent that you described with respect

to comparison of Figs. 4, 5 and 11 of the third Carter patent in suit?

A. Yes, sir, these structures labeled 1 and 2 in Fig. 1 of the patent of addition, where three wires are shown stretched along in parallel forming each side of the V, are the equivalent of the single wire V or are the equivalent, [fol. 361] as Mr. Hogan pointed out in connection with the third Carter patent, in connection with Figs. 4, 5 and 11, the equivalent of single wires on a side.

Q. 479. Will you compare the disclosure of these two French patents to Levy, that is, the original and the patent of addition, with the disclosure of the second Lindenblad patent?

A. Again assuming that Fig. 2 of the second Lindenblad patent is for a standing wave antenna, then Fig. 1 of the Levy patent of addition is of course the same thing.

Q. 481. Will you refer to the Brown British patent, 1449, of 1899, and point out its relevancy to any of the three antenna patents?

A. Yes, sir. This Brown patent deals with an antenna system in which the radiating members are linear conductors which are excited in phase opposition with standing waves and are spaced with respect to one another in order to obtain a directional effect.

Referring to page 2 of the specification, the part headed "Complete Specification", the second paragraph, "According to this invention, the transmitting apparatus is provided with two radiating wires coupled one to each terminal of the sparking device and the receiving apparatus is provided with two receiving wires coupled one to each terminal of the coherer."

Q. 482. What is a coherer?

A. A coherer is a detector of high frequency current that was used in the early days of the art—radio frequency.

Mention is made here in the one sentence to both sending and receiving. The same principles, of course, will apply. [fol. 362] The sparking device referred to is in connection with the transmitter and takes the place of the source of oscillations. When we speak of using a generator or a vacuum tube oscillator or what-not, that is the source of high frequency oscillations.

Continuing: "These radiating and receiving wires are respectively placed at a distance apart which has a definite relation to the length of the signaling wires, that of half a length being a convenient distance." And skipping the next sentence, "This placing the wires half a wave length apart causes the system to send its waves or receive them from mainly one direction, which direction would seem to be that of the plane of the wires. If the vertical wires were not so carefully adjusted to the wave length they would transmit or receive the Hertzian waves from any direction."

Referring now to Fig. 1, the radiating wires, the linear conductors are A and A′. The source of oscillations, namely, the sparking device labeled S, excites the wires A and A′ in phase opposition, that is, it produces standing waves of the opposite instantaneous polarity on these wires. These wires are electrically short. In being electrically short, that is, not being more than a half wave length, certainly the individual wires would radiate in a direction perpendicular to the wire most favorably; consequently, that is the direction of principal radiation as far as these wires are concerned. Being excited in phase opposition and being spaced as Brown pointed out in the passage that I read, namely, one-half wave length apart, that spacing is the [fol. 363] proper spacing in order to obtain perfect addition in the direction of maximum radiation. And in fact the statement which Brown here makes, namely, that radiation would seem to be, as he puts it, in the plane of the wires, recalls a similar statement made in the first Lindenblad patent in connection with Fig. 3. On page 2 of the first Lindenblad patent, page 2, line 127, referring to Fig. 3: "In a direction normal to the plane of the conductors 14 and 16" (these are the wires of the radiating system) "radiation is cancelled because of the phase opposition of the energy in the conductors, and consequently the hollow cones of radiation indicated in Figure 2 are reduced to four ears or lobes, the axes of which lie in the plane of the conductors."

That is, Lindenblad is here saying that by the arrangement of Fig. 3 the radiation will be confined largely to the plane of the wires, but as I have previously pointed out, it is necessary, in order that this be true, that the wires be properly spaced. This Brown British patent that I am

speaking of truly gives the correct spacing as well as stating that radiation would seem to be in the plane of the wires.

On page 3 of the Brown British patent, line 48, he states:

"The radiating wires aa^1 and also the receiving wires a^2a^3 are respectively placed at a distance apart which has a definite relation to the length of the Hertzian waves generated. This distance may be conveniently half that of the Hertzian wave length, such an arrangement causing the positive radiating wire to supply the positive crest of the wave at the same time as the negative radiating wire sup- [fol. 364] plies the negative crest of the wave and the waves to be thus transmitted or received mainly in the direction of the plane of the radiating and receiving wires."

He describes here in words again what I showed in one of the exhibits where I said you could trace the side waves with your fingers without having to change the distance between them when addition was in phase, that is, perfect addition; otherwise it would be impossible to maintain a constant distance between the fingers in tracing the two waves. And I also pointed out that the reason they came into phase was the difference in path, the distance that they had to be traveled. That is what Brown means here when he speaks of the positive crest of the wave radiating at the same time as the negative radiating wire supplies the negative crest of the wave so that they will then come together.

Q. 487. Now, what would have to be the necessary relation of the wires of the antennæ in order that radiant action would occur in a direction making the same angle with each conductor?

A. The wires in that case would have to be parallel.

Q. 488. Would that language that I read to you correctly or incorrectly describe the antennas employed by the defendant?

A. That language would incorrectly describe the antennas employed by defendant.

Q. 489. Will you please turn to the Takagishi Japanese patent 70,583 of 1926, and point out its pertinency from the translation and the drawings to the subject matter here in issue?

A. As far as the drawings are concerned, I am afraid I will have to adopt my own system of numbering, since I cannot read Japanese.

[fol. 365] Q. 490. All right, do so. Might I suggest that you use the system adopted by the translator, because the translations have been agreed upon?

A. This patent of Takagishi relates to a short wave directional antenna system in general, and in particular to an antenna system composed of linear conductors a plurality of half wave lengths long excited in phase opposition, that is, with standing waves of opposite instantaneous polarity. This is indicated in what I shall refer to as Fig. 1, the upper right hand figure on the first page of the figures. Here two wires a and a′ are shown, the designation a and a′ being at the upper ends of the wires. The straight line extending from these crosses are the wires. The curved lines shown on there represent current distribution, and are drawn so that they indicate an opposite polarity distribution from the wire a′, that is, the one on wire a is opposite that of a′.

The next figure to the left shows a generator feeding the wires shown in a circle with a little sine wave symbol in the circle.

The figure immediately below the last mentioned figure, which I believe is Fig. 4, shows a second pair of linear oscillators arranged in the same plane as the first pair in order to obtain a reinforcement of the radiation from the first pair. It appears that in this patent to Takagishi his instructions as to spacing are not all that one might desire, but in that respect they are just as good as those given in Fig. 3 of the first Lindenblad patent, Takagishi starting out with two electrically long wires excited in phase opposition and collaterally spaced.

He wanted to do more than that, he wanted to control [fol. 366] the angle of radiation, that is, the angle with the horizontal, by adjusting his second wire, that is, he wanted to do something in addition to merely placing the two wires in parallel. But as far as his showing the starting point, two wires excited in phase opposition which are electrically long and parallel and collaterally spaced, the information contained here is just as good as that contained in Fig. 3 of the first Lindenblad patent.

Q. 492. What does Takagishi do with his wires, does he offset them at an angle with respect to each other, referring to the drawing which you called Fig. 1?

A. Yes, sir, he offsets them at an angle with respect to one another in order to obtain his control of direction that I mentioned.

Q. 493. How does that angle compare with the angle shown in Fig. 4 of the Lindenblad patent, No. 1,884,006, and designated by the reference symbol alpha? Is that the same angle?

A. No, sir, it is not. He varies it and it may have any number of values. He describes an experiment in here in which he does try several values.

Q. 494. Several values for the angle theta?

A. He calls it the angle theta.

Q. 495. Is it or is it not the angle of offset between the wires in exactly the same sense as the angle alpha is employed in Fig. 4 of the first Lindenblad patent?

A. It is the angle of offset of the ends of the wires.

Q. 496. Now, will you please proceed with the translation, pointing out the passages thereof which are pertinent?

A. On page 2 of the translation, the first sentence:

"The purpose of the invention is to furnish a directional [fol. 367] antenna by which a desired result can be readily obtained at will when most of the energy of the electric waves is radiated in wireless telegraphy and wireless telephony at a given altitude above the ground, or in receiving the electric wave traveling through the air at a given angle. Furthermore, this invention makes possible efficient communication by adjusting the radiation angle depending on the distance between the transmitting and receiving stations and depending also on the seasonal and atmospheric conditions. This applies particularly to short electric waves which are noted for their properties of reflection and refraction functions."

In other words, this patent is directed to the short wave antenna system.

Then on page 3, the last sentence in the first paragraph, or, rather, the second sentence in the first paragraph:

"It has been theoretically proved that when, as has been known in the past, a vertical antenna of a comparatively short wave length is employed for transmission, the energy

of the electric waves is greatest in a horizontal direction. On the other hand, when the antenna is replaced by an antenna which has a large natural wave length, the direction of the radiation of maximum energy of the electric wave is to some extent inclined to the horizontal."

What he means to say there is, of course, antenna which is electrically long, rather than an antenna which is elec- [fol. 368] trically short, and there follows, near the bottom of the page a table indicating what he means, that the angle to the horizontal, that is, the angle to the perpendicular to the wire is given in the second column for the number of harmonics, that is, the number of half wave lengths or quarter wave lengths in this case, since it is grounded, corresponding to different lengths of wire, that is the number of harmonics would be three-fourths, four-fourths or one, and for 15 it would be three and three-fourths wave lengths long.

He stated on page 7 of the translation in the first full paragraph:

"What this inventor desires to secure by this patent are points other than those already known."

I mentioned that in addition to using the wires in parallel, he wants to obtain, in addition to that, the control of the angle of radiation over and above that.

Q. 498. I call your attention to the statement on page 4 of the translation beginning with the words "in accordance with this invention".

A. Oh, yes, about the middle of page 4:

"In accordance with this invention, the bulk of the radiated energy is directed at some angle to the horizontal plane. This is controlled by proper positioning and phasing of the two vertical antennæ instead of primarily choosing the order of the harmonics has been done heretofore."

Q. 499. What does that mean?

A. That means, the proper phasing, being phase opposi- [fol. 369] tion in this case; and proper positioning meaning the proper spacing apart of the wires.

Q. 500. Will you now refer to the Heising patent, 1,562,-961, and particularly Fig. 10 thereof, for its bearing on this question?

A. This patent to Heising also refers to a directive antenna system consisting of parallel antenna wires, a plurality of wave lengths long. He mentions in the specification a length of 12 wave lengths long, extending on one side only of the source. The wires are spaced laterally, that is, apart, and longitudinally, that is, staggered, and properly phased in such a way that one pair of principal lobes of radiation is cancelled, whereas the other pair of principal lobes of radiation is strengthened.

That is diagrammatically illustrated in Fig. 10. In Fig. 10 the wires are 20 and 21. The wires are staggered as to their ends as shown, and are spaced collaterally as described in the specification. Referring to page 4, line 122, he states, referring to Fig. 10:

"As is diagrammatically indicated in Fig. 5, there is directive radiation in two lateral directions. An arrangement of multiple antenna for suppressing radiation in one of these directions is illustrated in Fig. 10, in which parallel directive antennæ 20 and 21 are shown spaced with their respective energy transmission loops 22 and 23 from the terminals 24 and 25 connected with the source extending in the same direction and neutralized in space. If energy of the same phase is simultaneously supplied at points 24 and 25, and if these points are a half a wave length apart in one direction in which their respective antenna radiated [fol. 370] most powerfully, the effect of the energy radiated from the point 25 will be to oppose and neutralize that radiated from point 24 in this direction."

This is for the reason that for all points in space in this direction, these radiated energies will be opposite in phase, in other words, loop 22 will neutralize loop 23.

If the distance between the points 24 and 25 does not correspond to a half wave length, the phase of the energy supplied to one of the antenna may be so shifted by a variable impedance device 30 that the points 24 and 25 will tend to radiate energy which will neutralize in space in the direction of loops 22 and 23. This will leave only the loops 26 which are similarly directive and which are additive.

In connection with the loops, as Heising calls them, and we have referred to them as lobes of radiation, Fig. 8 of this Heising patent shows diagrammatically what these

lobes mean. The antenna in Fig. 8 is shown by the horizontal line to the left ending in an arrow head, the direction only being significant.

This patent relates to traveling wave antennæ. That is the reason why we have two major loops or lobes of radiation, rather than four major lobes of radiation.

What Heising does then in the arrangement shown in Fig. 10 is equivalent to what was intended to be accomplished by Fig. 4 of the first Lindenblad patent.

Heising shows correctly how this is to be accomplished. The loops 22 and 23 are shown radiating from correspond- [fol. 371] ing points on the two wires. It so happens that the stagger of these wires is about 45 degrees. And it also so happens that a line drawn from 25 to 24 would be parallel with the ends of the wires, and would also be in the line of the lobe of radiation.

That the distance between the points 25 and 24 is arranged to be worked to an odd number of half wave lengths, and consequently at a distinct point such radiation in this direction would be cancelled.

On the other hand, radiation from 24 and 25, extending in the directions 26, since the starting points in that direction are the same, there will be perfect addition of the loops in that direction.

When this is accomplished, it results in a unidirectional characteristic without the addition of a second similar pair of wires for the simple reason that the units composing a combination of Fig. 10 are themselves traveling waves, and they will therefore not be any oppositely directed lobes, but the lobes inclined to each other as shown in Fig. 10.

Consequently, it is not necessary to add as was intended in Fig. 5 of the first Lindenblad patent, a second similar pair of wires in order to remove one of the bidirectional lobes of radiation and confine the radiation in one direction.

Q. 503. Now, referring to Fig. 8 of this Heising patent, I find again an angle designated by theta, extending between the direction of radiation of the lobe and the antenna. Is it or is it not the same angle alpha or theta of the third Carter patent?

A. No, sir, it is not the same, because in this case it designates an angle of principal radiation from a traveling wave [fol. 372] antenna in which phasing devices have been added to reinforce—approximately speaking—to reinforce the

lobe in some other direction than the lobe which is nearest the wire.

The designation of this as an angle, that is merely to designate it as an angle of principal radiation, or the angle which Heising intends to use.

Q. 504. Now, will you please refer to the specification in this Heising patent, page 1, line 91, and explain what is meant by that?

A. At page 1, line 91, it states:

"The invention permits radiation in one lateral direction to the substantial exclusion of radiation in any other by an arrangement of parallel antennae."

That is what I have been describing in connection with Fig. 10.

He means by that to eliminate one of the sets of lobes and to arrange for the perfect addition of the other sets of lobes.

Q. 506. I come to the sentence at line 5, page 2, which states:

"The antenna may also be curved laterally to add to the focusing effect."

Now, what bearing, if any, has that upon Fig. 1 of the second Lindenblad patent? Does that or does that not suggest a laterally curved antenna, such as Fig. 1 of the second Lindenblad patent?

A. No, sir, because in this case, in addition to the curve, there is a change in the loading used on the antenna and the [fol. 373] focusing effect here, as I understand it, is for a nearby point, a comparatively nearby point.

Q. 507. Will you now refer to the article by Melton in the Q. S. T. book?

A. In this Melton article in Q. S. T. of August, 1926, there is shown in Figure 1, diagrammatically, a whole series of linear radiators of differing electrical lengths.

They are shown for every quarter wave length, from one-quarter wave length to eleven quarter wave lengths, in other words, all the way from a ground antenna, at its fundamental, one-quarter wave length, to an electrically long linear conductor, with standing waves throughout its length. These are shown, as indicated in Figure 1 as 10 meter radiat-

ing systems. In other words, short wave radiating systems.

In the heavy printing under the figure, the last paragraph in that heavy printing, states:

"While the antennas shown are vertical it is possible to operate the ungrounded ones in any position; both the grounded and ungrounded ones may be bent instead of straight."

What he means by bending them is taking the very long vertical antenna, to bend it over horizontal, and consisting of wires which are electrically long, and co-operate with its image in the ground. As I have pointed out in connection with other references this image will be excited automatically in phase opposition, and then becomes equivalent to Fig. 3 of the first Lindenblad patent.

Q. 509. Will you next point out the significance of pages 156 and 157 of the Mills book?

[fol. 374] A. In this book by Mills, entitled, "Radio Communication, Theory and Methods," he gives on the pages indicated general formulae applicable to determining the directional effects of any antenna. These formulae are given on page 156 and he shows in particular one use, namely that of determining spacing and phasing in order to eliminate radiation in one particular direction, and also what the radiation will be in other directions; and the conclusions on page 157, the end of that section, that is, the end of the first full paragraph:

"This general method may be applied to determining the directive effect of any combination of antennae."

That is used in a general way, the principles involved in these formulae may be applied generally. In other words, all of these problems connected with directional transmission, concern two things, spacing and phasing.

Q. 510. Will you compare very briefly the disclosure of this Mills book insofar as it is directed to reflector action with the disclosure of the first Lindenbiad patent and the third Carter patent in suit?

A. Well, referring on page 156 of Mills to the formulae below the figures, he states—let me read first the sentence beginning just above the figures:

"Let the phase theta and the distance d be so chosen that at P sub 1, the effects of the two antennae neutralize."

Referring to Fig. 113, P sub 1 is taken on a line with the two antennas A sub 1 and A sub 2.

Continuing: "Then a difference in phase of pi must exist between the two effects."

[fol. 375] In other words, they must be in opposition 180 degrees apart.

Then he sets down his equation which represents this condition mathematically, and the next two equations merely show explicitly in terms of theta the difference in phase between the two antennas A sub 1 and A sub 2. Taking the last expression where theta equals pi plus or minus 2 pi d divided by lambda, it is seen that whenever d is one-quarter of a wave length, that is lambda over 4, or for that matter, any odd multiple of quarter wave lengths, theta will be equal to plus or minus pi over 2, which in radians is the same thing as plus or minus 90 degrees, which is referred to generally in the literature as phase quadrature. And that represents the condition where there will be cancellation in one of the two opposite directions and addition in the other of these two opposite directions.

Q. 522. With reference to the second Lindenblad patent in suit, No. 1,927,522, Mr. Hogan has advanced as the advantages of this patent, and I am reading from the answer to Q. 66 (R. p. 174):

"The principal advantages of this Lindenblad diverging long wire antenna are its simplicity, its cheapness, its operativeness over a considerable range of frequencies, and its ease of erection, maintenance and adjustment."

Are there any instances in the prior art to which you have referred where those advantages are all obtained?

A. Those advantages would be obtained in both Bethenod's and also in Levy.

Q. 523. Finally in reference to the alleged advantages of [fol. 376] the third Carter patent, as given by Mr. Hogan, in answer to Q. 81 (R. p. 189), they are, "First, the exceptionally high directivity per unit of the antenna system." What instances of the prior art, if any, would give that same advantage, and in this connection, Mr. Kelley, you may include in the prior art the first two Lindenblad patents?

A. The first Lindenblad patent certainly if arranged as it was intended to be arranged so as to obtain the intended object, would be fully as directive as the third Carter patent.

Q. 524. And the second point of advantage is "its low cost

of erection and maintenance." What instances of the prior art can you there refer to?

A. It would amount in the case of comparing the first Lindenblad patent with the third Carter patent, of a few poles difference in favor of the third Carter patent.

Q. 525. How about the comparison of the second Lindenblad patent to the third Carter patent?

A. In comparing the second Lindenblad patent to the third Carter patent there should be no difference at all.

Q. 526. The third point is its simplicity and stability of adjustment. Is or is not that advantage obtainable in the prior art, referring to the first and second Lindenblad patents?

A. That advantage is obtained when the first Lindenblad patent would be arranged to accomplish the intended object and of course the second Lindenblad patent likewise.

Q. 527. The fourth point is the fact that it utilizes standing waves effectively and there is no need to minimize them either by having exceptionally great length or by using [fol. 377] terminal resistors. Is that advantage obtainable in either of the prior Lindenblad patents?

A. Yes, sir, it is obtainable specifically in the first Lindenblad patent which is for a standing wave antenna.

Q. 528. If the second Lindenblad patent discloses a standing wave in its Fig. 2, then——

A. If the second Lindenblad patent is to be understood to disclose a standing wave antenna system, then the same advantage applies there.

Q. 529. Now, the fifth point of advantage is its adaptability to successful use with a wide range of lengths of wires and lengths of wave. If that is an advantage of the third Carter patent is it likewise an advantage in any reference to the prior art to which you have referred?

A. It is equally true of the first and second Lindenblad patents.

Q. 530. The sixth advantage is its high radiation efficiency?

A. Well, that would be equally true of the first two Lindenblad patents.

Q. 531. The seventh advantage is that if the side wires are longer than about six wave lengths in length it has relatively high directive efficiency for a considerable range of wave lengths in any one structure?

A. That is true also of the first two Lindenblad patents.

Q. 542. Now, in answer to X Q. 819 (R. p. 282), Mr. Hogan

testified: "There are no statements in the second Lindenblad patent as to angle"—and Mr. Hogan testified in answer to X Q. 822 (R. p. 283), where he was asked: "What do you mean by a gradually diverging V?

A. I think there is no numerical limit to such a word as 'gradually' but for practical purposes, I would expect the angle to be of the order of 45 degrees or less, certainly less [fol. 378] than 90 degrees." And in that connection it is noted that Defendant's Exhibit G shows an angle of 122 degrees. Have you had worked out wave patterns illustrating exactly the same results in so far as direction of predominant radiation is concerned with an angle less than 45 degrees?

A. Yes, I have. In this case there is an angle of 40.8 degrees, and the wires are 16 wave lengths long, the radiation in the direction of the axis of the conductor system is approximately zero, this being an angle which is within the 45-degree angle.

Q. 543. And in what direction would the radiation be predominant?

A. Predominant radiation will be in a direction other than the bisector or the axis of the conductor system, in substantially different directions, they would not be confined all in one direction.

Mr. Darby: I offer the chart produced by the witness in evidence.

(Marked Defendant's Exhibit BB in evidence.)

Q. 544. In cross-examination Mr. Hogan stated at X Q. 819 (R. p. 282), in answer to this question: "Does the patent, if there is a possibility even that that general statement is not true, does the patent tell you what is the limit of angle between the legs of the V, where it will obtain the results of the patent or where it will not do so?" referring to the second Lindenblad patent. The answer is: "There are no statements in the second Lindenblad patent as to angle whatever and no numerical limits given. There are given a set of recommended cases, wherein the wires are five to ten wave [fol. 379] lengths long, and the spacing is about one-fifth the length of the wire."

Have you had radiation patterns made to illustrate where, under the conditions given by Mr. Hogan, the major or predominant radiation would be obtained?

A. I have.

Q. 545. Will you please produce them and point out where it would be obtained under the conditions given by Mr. Hogan, and in what respect, if any, they conform with the teaching of the patent?

A. There are two radiation patterns, one of which is for a length of the sides of a V of four wave lengths, and the other is for a length of eight wave lengths.

Referring first of all to the V which has a length of four wave lengths, there is plotted here the radiation diagram which would be obtained with the spacing at the open end one-fifth of the length of the wires, as Mr. Hogan pointed out. The wires are shown in the figure extending to the right of the center, they are not very distinct, coming out pretty near to the valley of the small lobe that is right near the No. 2. Those two lines inclined to each other show the direction in which the wires of the side of the V extend. The axis of the antenna system of course is the line right through the middle from zero to zero degrees.

With this V, there is a space at the outer end one-fifth of the length of the wires and with each side of the V four wave lengths long, it can be seen that not only does predominant radiation not take place along the axis of the conductor system, but the predominant radiation is in the directions which lie wholly outside of the wires forming the system.

[fol. 380] And referring to the radiation pattern, V antenna, where the sides are eight wave lengths long and the opening is again, in accordance with Mr. Hogan's specification, that is, one-fifth of the length of the wires, it is seen in this case the wires being drawn in similar to the other diagram, that radiation is not only not predominant along the axis of the system, but also that it is predominant in directions outside of the wires forming the system. In other words, these two diagrams taken together cover the range of from four to eight wave lengths on a side and show the same effect, the difference between the two, that is, if one went gradually from one to the other, there would be gradation from one to the other.

Mr. Darby: I offer in evidence the chart produced by the witness with reference to the four wave length antenna.

(Marked Defendant's Exhibit CC in evidence.)

Mr. Darby: I offer in evidence the chart produced by the witness marked eight wave lengths antenna.

(Marked Defendant's Exhibit DD in evidence.)

Cross-examination.

By Mr. Blackmar:

X Q. 546. Mr. Kelley, in your direct examination, you told us your experience and qualifications with respect to cable, telephone, telegraph and carrier currents. I would like to get an idea of what your practical experience in radio has been.

A. Well, as you recall, I stated that my training had been in radio engineering, and all during my professional experi- [fol. 381] ence, I have been applying radio engineering principles to my work, and I have had some experimentation, that is, some work with my own hands, with radio. But if I may answer your question fully, Mr. Blackmar, I would like to relate briefly something of my own experience in connection with what I have to say.

I have done many jobs—engineering jobs of which I had never seen any of the equipment or apparatus either during the process of manufacture or installation, which I designed and kept in touch with by correspondence, and had satisfactory reports of successful operation, so that as far as I am concerned, it is not always necessary that I handle these things with my own hands.

I have had much experience of that nature, and you must appreciate that engineering principles are not things applied to a very limited range of application but are of very wide application.

So far as these patents in suit are concerned, I am familiar with the theory, and they are largely theoretical, as you will probably appreciate, and as far as impedance matching transmission lines, and so forth, are concerned, I have had years of experience with that, and these distinctions as to frequency, which I think is implied in your question, are wholly unwarranted from the standpoint of engineering.

The engineer wants to know frequency, to be sure, but when he knows frequency, he knows what to do. In certain cases I know that he will find that he can make certain approximations which are readily available from the formulas that are employed, and so forth.

All I wanted to point out is that so far as climbing poles and making adjustments and conducting, you might say,

[fol. 382] radio transmission development of apparatus, I must admit that I have not had that sort of training.

X Q. 547. How about making measurements in the field?

A. I have made measurements experimentally. It has not been my job to go out and make them.

X Q. 548. When has been your first experience with respect to directive antenna design and construction?

A. As I told you, I have not actually done that sort of work. I have followed the art, and I know and understand and can explain what it all means.

The principles involved are of general applicability.

X Q. 990. When you said certain angles were used to intentionally secure certain results, you did not then mean the antennas were set up with those angles with those results in mind?

A. I cannot testify to that of my own knowledge.

X Q. 991. You testify as to what occurs in the antennæ after they are built, that is your testimony?

A. I am speaking of it functionally, and I use the word "intentionally" merely to indicate that that was the function.

X Q. 1061. Will you please refer to Q. 401 (R. p. 322), sentence beginning, where you were discussing, I think, defendant's antenna No. 2; you stated:

"And it is seen by comparing the two right hand figures that instead of sacrificing any real radiation by virtue of using a different angle, a different angle is used deliberately in order to gain more radiation in the direction in which it actually goes out."

[fol. 383] Now, from what you have already stated, I assume that you do not intend that to mean that you know the angle was chosen deliberately for that purpose when the antenna was set up, is that correct?

A. Clearly you know the knowledge that I possess in that respect from my previous testimony.

X Q. 1062. In other words, you are merely testifying to results?

A. The functioning.

X Q. 1063. What the functions are and what the result would be, as I understand it?

A. That is correct.

X Q. 1064. Similarly on the preceding page, you state that defendant is not relying on that theoretical radiation, and the same thing is true of that, as I understand it?

A. Yes, of course.

X Q. 1065. Again in answer to Q. 403 (R. p. 323), about the sixth line from the end of the paragraph:

"by an apparent sacrifice in the theoretical radiation defendant departs from the teaching."

That, again, as I understand it, is merely your conclusion as to the effect of the structure as it exists?

A. As it exists, yes, sir.

X Q. 1066. I am asking you each one of these, Mr. Kelley, so there won't be any misunderstanding later on.

A. Yes, sir.

X Q. 1067. Or I trust there won't. Again on page 309, Q. 356, you state: "In defendant's structure, it"—meaning the angle—"is 45 degrees. The reason for this being that by using this angle different from the Carter," certain effects are obtained. Again, you don't mean to suggest that [fol. 384] you know why any particular angle was chosen, or do you mean so to suggest?

A. I don't mean so to suggest. This is all as to the functioning. As I have already said before, I have no knowledge of when they were designed, who did it, or what they did. I have only seen them as they exist.

X Q. 1068. Or why they were designed in certain ways or what they hoped to accomplish with them outside of possibly directivity or something of that kind?

A. Yes, only as they exist.

X Q. 1069. With respect to defendant's Exhibit S and T, will you please first state on the record whether these are intended to represent relative power or relative amplitude?

A. Relative power, sir.

X Q. 1070. And in the four right hand diagrams, there is, as I understand it, assumed to be some kind of earth over which the antenna is erected?

A. It is assumed to be perfect earth—perfect ground, but if you care to see them, we have it for very poor ground and they will show the very same general state of affairs, if you wish to have me produce them.

X Q. 1071. From that, as I understand it, these diagrams are calculated, are they not?

A. Yes, sir, they have been calculated.

X Q. 1072. They do not represent any actual measurements of antenna field strength or power or anything of the kind?

A. No, sir, they don't represent actual measurements. They were calculated.

X Q. 1073. So that the statement at the top over the right hand figures in each case, "What it actually is," is not intended——

A. Is not——

X Q. (Continued.) —is not intended to indicate that that [fol. 385] was based on actual measurement?

A. No, it is not intended to indicate other than that it was calculated.

X Q. 1074. That means "what it actually is" in your opinion or in the opinion of the person who made these calculations, is that correct?

A. That is correct, sir.

X Q. 1075. And I assume you did not make the calculations?

A. No, sir, I had them made.

I would like to correct an answer that I made right at the close of last night, or yesterday's session, an answer that I made without sufficient reflection. I am referring to X Q. 1074, which reads:

"That means"—referring to Defendant's Exhibits S and T—"That means what it actually is in your opinion or in the opinion of the person who made these calculations, is that correct? A. That is correct, sir."

I did not wish to imply by this answer that mathematical calculations are a matter of opinion; were it not for the use of mathematical calculations, engineers would be helpless, and to cite one example, in the building of the Holland Tunnel, where the computations which preceded this work enabled the engineers to meet in the middle of the river with very few inches to spare; and I do not believe I need to laborate any further than that, namely that mathematical processes and calculations form the substantial assistance to the engineer without which he would be helpless; and also that such calculations are, of course, subject to checking. It is possible for one to make a mistake. It is also possible for one to discover a mistake or for somebody else to check these calculations.

[fol. 386] X Q. 1078. I was about to ask you that: Calculations are not always correct?

A. That is correct. They are subject to checking, using well-known mathematical principles.

The Court: What you really meant was that the calculations formed the basis on which you formed the opinion?

The Witness: You could put it that way, your Honor.

The Court: That is what you meant?

The Witness: Yes, your Honor.

X Q. 1079. You spoke of the Holland Tunnel. Do you remember an incident in connection with the bridge being built across the St. Lawrence River at Quebec?

A. Well, my only reply to that is: "To err is human," and applying mathematical principles wrongly, of course, leads to wrong results, and that, of course, is subject to checking, and any of these calculations that we have produced, we are only too glad to have your expert and your engineers go over them and point out wherein they agree or disagree, so that there be no conflict in that respect.

X Q. 1080. In order that my question may be understood, does your recollection check with mine, that there was a cantilever bridge to be built across the St. Lawrence River near Quebec which collapsed prior to its completion, I think, twice?

A. As I recollect, they had considerable trouble with that bridge, and it did collapse.

X Q. 1081. And another thing that is necessary in arriving at a correct mathematical result is to make correct assumptions in the first place?

A. Oh, yes, that is always true.

[fol. 387] X Q. 1082. And in addition to that, mathematics, when applied to practical situations, do not always come out in accordance with expectations, possibly because there are factors that may be overlooked or that are not understood, is that correct?

A. Well, in a general way it is correct, but actually engineers have been pretty successful in predicting their results, and I have had some experience in that line myself.

X Q. 1083. Was Steinmetz a recognized mathematician?

A. Steinmetz was recognized to be a leader in his art.

X Q. 1084. How about John R. Carson of the Telephone Company?

A. Yes, sir, John R. Carson, to the best of my knowledge, is considered to be a very fine mathematician.

X Q. 1085. Are you familiar with the fact that they did not agree as to certain developments on the question of wave propagation along parallel wires?

A. It is quite possible they did not agree, and I am sure they could find the point of disagreement and check each other's calculations.

X Q. 1087. Will you please refer to Questions 292, 293 and 294 (R. p. 296). Q. 292 is: "Referring to defendant's antenna, in the case of any antenna employed by defendant, is the propagation of the radiant energy predominantly in the plane of the wires?

A. No, sir, the radiation is sent out at a considerable angle, a substantial angle, to the plane of the wires.

"Q. Is that accomplished accidentally or as a matter of design?

"A. That is accomplished as a matter of design.

"Q. For a particular purpose?

"A. Yes, for the——"

[fol. 388] Then the answer was interrupted.

Again, in view of what you said yesterday, I understand that you would not want that answer taken to mean that you know the purpose of the design of these antennas at the time that they were erected?

A. No, sir, inasmuch as I did not participate in the design of these antennas.

X Q. 1088. And what is stated there is your opinion as to the actual action of the antennas after they had been set up, is that correct?

A. That is correct, yes, sir.

X Q. 1089. How were these antennas designed (using "design" in that sense) to accomplish this result, namely, radiation at an angle from the plane of the wires?

A. As I explained in my direct testimony this result is accomplished by erecting the antenna with the wires parallel to the surface of the earth, and having such an angle between the wires that the radiation which is sent out by the wires, in conjunction with the negative image of the antenna system in the earth, will radiate better at an angle to the horizontal than in any other direction, the angle being

desirable because of the nature of the transmission requirements for short waves through space.

X Q. 1090. In the absence of ground effects what direction with respect to the plane of the wires would the predominant radiation have been in?

A. Without the ground effect, you mean an antenna——

X Q. 1091. In free space?

A. In free space, in other words, a theoretical consideration, then it would be in the plane of the wires, substantially in that direction.

[fol. 389] The Court: Instead of shooting straight you want to take advantage of the trajectory, is that the idea?

The Witness: Yes, sir, that is the idea.

X Q. 1092. But it is the ground effect that causes that result?

A. It is the co-operation between the antenna and the ground that accomplishes that result, yes, sir.

X Q. 1093. And referring to Defendant's Exhibits S and T, the left hand diagrams indicate, I believe, what you have just stated, that is, in free space the antenna would radiate in the plane of the wires predominantly?

A. That is correct, sir.

X Q. 1094. How could you build a horizontal antenna and avoid this ground effect?

A. Well, you might build one on an airplane, a rather unusual thing to do. I do not mean that to be taken literally, because airplanes do have antennas. But, as you can readily see, it would have to be removed from the ground.

X Q. 1095. In other words, in practical cases with respect to antennas in fixed locations, the ground effect always enters into the radiation pattern, always affects the radiation pattern, does it not?

A. It must if the antenna is constructed on the ground.

X Q. 1096. By "on the ground" you mean to include 80 feet above the ground?

A. Yes, sir, of course.

X Q. 1097. Do you know what the character of the ground at Sayville is?

A. I am not familiar with it in detail, but I understand it is not of the best characteristics. I cannot give you the details, but I can obtain them for you if you wish.

[fol. 390] X Q. 1098. Is it perfect ground?

A. No, there is no perfect ground.

X Q. 1099. That is a mathematical assumption?

A. It is an assumption that is usually made by engineers, certainly in making the first calculations in respect to what they expect to get in the way of radiation from a given antenna.

X Q. 1100. Then the actual character of the ground, since you say it is not in practical cases perfect, modifies those conclusions to a greater or less extent, doesn't it?

A. It modifies the conclusions in certain respects and in other respects, relative values may remain pretty much the same.

X Q. 1101. But in some ways it does alter the conclusions?

A. In some ways it does alter the conclusions, yes, sir.

X Q. 1102. Then I take it from your prior answer you cannot tell me in general the conductivity or dielectric constant of the ground at Sayville, is that right?

A. I cannot tell you offhand, but I can obtain that information for you if you wish it.

X Q. 1103. Will you be prepared to give it to me after the noon hour?

A. I will try to. I am not absolutely sure that it is available, but if it is I will do so.

X Q. 1104. I think it is already on the record, but will you state again as to the left hand diagrams of Defendant's Exhibits S and T, whether or not in those cases the ground effect is neglected?

A. You are holding two diagrams. In the left hand figures the ground is entirely neglected.

The Court: In laying out these systems do you do it without regard to the ground and then alter it to change the [fol. 391] situation as the ground may require, or do you attempt to anticipate the effect of the ground?

The Witness: The effect of the ground, your Honor, is anticipated in so far as it can be practically. Ground conditions vary even in the same location, but in general one can obtain a fair picture of what the result will be.

The Court: And then you make the modifications that may be necessary by reason of any change in those conditions,—practically?

The Witness: Yes.

The Court: You anticipate?

The Witness: Yes.

The Court: But if your anticipations are not completely realized then you modify your systems to meet the conditions, practically?

The Witness: That could be done.

The Court: Is it done or are they always so exact that they strike it right?

The Witness: Your Honor, the matter has been so thoroughly analyzed in the art that a pretty good guess can be made at the outset.

X Q. 1105. A good enough guess ordinarily?

A. A good enough guess ordinarily, yes, sir.

X Q. 1106. Will you please refer to the third Carter patent in suit and look at Fig. 7; in general do you not understand that that shows substantially the same with respect to the operation of a V antenna as is shown in the left hand figures of Defendant's Exhibits S and T?

A. In the vertical plane, yes, sir.

X Q. 1109. That is what it states?

A. Yes, sir.

X Q. 1110. And it also states, does it not, "Ground effect neglected"?

[fol. 392] A. It so states, "Ground effect neglected," but if I may I would like to also refer to Fig. 6, which is in the horizontal plane.

With respect to that figure, no such modifying title is given and consequently one must assume that Carter has in mind that some effect due to ground would happen in the case of Fig. 7, but not in the case of Fig. 6, which shows it in the other plane.

X Q . 1111. Now, you have stated, I think twice, on the record that the defendant uses only V antennas. Am I to understand that you intended to imply that it uses no other types of antennas at its Sayville station than V antennas?

A. I was referring always to the antennas in the stipulation.

X Q. 1112. So far as you know, there may be, or you do know that there are, other types of antennas used there?

A. I believe there are other types of antennas used there, but I am not familiar with what they are—I cannot give you a list of them.

X Q. 1113. Now, if one of the defendant's V antennas, such, for example, as antenna No. 1 or antenna No. 5, were

in free space, would the radiation be predominantly along the line of the bisector of the angle of the V?

A. Numbers 1 and 5?

X Q. 1114. For example, numbers 1 and 5, yes.

A. Yes, sir, I believe it would.

X Q. 1115. And is that also true with respect to the other of Defendant's V antennas which are covered in Plaintiff's Exhibits 7 to 13, inclusive, that is, all of the V antennas?

A. Yes, that is substantially true.

X Q. 1116. You state that as these antennas are set up, the radiation is sent out at a considerable angle, a substan- [fol. 393] tial angle to the plane of the wires. That appears in answer to Q. 292 (R. p. 297). Can you state what this angle is?

A. It is shown on Exhibits S and T.

X Q. 1117. Is it the same for all antennas, you mean?

A. Not necessarily the same for all the antennas.

X Q. 1118. As a matter of fact, it is not the same for the two shown on Defendant's Exhibits S and T, is it?

A. No, sir, it is not.

X Q. 1119. Do you know what the angle is with respect to all of the antennas?

A. No, I couldn't say. That would have to be determined in the same way.

X Q. 1120. How would you determine it?

A. By applying the calculations well known in the art, assuming a ground which is poor enough to include the worst ground one would encounter in a given location, and to compute the resulting effect between the antenna system above the ground in cooperation with its image in the ground, under these conditions.

X Q. 1121. How could you check those results, Mr. Kelley?

A. They could be checked by means of an airplane and a suitable calibrated receiver by means of which relative values could be plotted.

X Q. 1122. And that would, however, be only approximate in its correctness, would it not?

A. Well, it would be limited to the error in precision of measurement, of course.

X Q. 1123. Which would be greater taken under those circumstances, than under more convenient circumstances, would it not?

A. I am not able to say what the error would be.

X Q. 1124. Did you ever try to make precision measure- [fol. 394] ments of that kind in an airplane?

A. No, sir.

X Q. 1125. Do you know what the angle at which it is desirable to propagate these waves is?

A. That angle is generally ten to fifteen degrees, and is based on experience as to what it should be because the transmission through space, that is, in the intervening region, has been and still is subject to experimentation and gathering of further knowledge.

X Q. 1126. It varies with a number of factors, does it not?

A. Yes, sir, it would vary with a number of factors. And it is with respect to these factors that I am referring when I speak of the experimentation and the increase in knowledge as time goes on due to the accumulation of data.

X Q. 1126A. The desirable angle of propagation of the waves varies with frequency, for example?

A. Well, the main factors involved, or, rather, the main factor would be the action of the ionized atmosphere which is utilized in the transmission of these waves from the transmitter to the receiver, and the altitude which varies, and, indirectly, the frequency comes in there, because different wave lengths we reach to different heights, so to speak, in this ionized atmosphere, and altogether it is a variable factor.

X Q. 1128. It depends upon the distance between the transmitter and the receiver?

A. Yes, sir, that is a factor.

X Q. 1129. Depends upon the time of day?

A. Yes.

X Q. 1130. Time of year?

A. Yes, sir.

X Q. 1131. And it is a rather difficult thing to determine [fol. 395] just what is best under all circumstances, isn't it?

A. Well, these factors, as I think we both agree are variable, and one has to accommodate the conditions of sending and receiving, as far as possible, to these factors.

X Q. 1132. Can you state the circumstances under which it would be preferable to propagate the radiation at, say, 18 degrees, rather than at 10 degrees?

A. No, I can not give it to you as detailed as that, no, sir.

X Q. 1133. As to the direction of the propagation from the

antenna, that also depends upon a number of things, does it not?

A. Yes, that would obviously depend upon a number of things, yes, sir.

X Q. 1134. It does not merely depend upon the angle between the wires, does it?

A. The angle between the wires is one factor.

X Q. 1135. Is one factor?

A. Yes, sir.

X Q. 1136. Height above the ground in wave lengths is another factor?

A. Yes, sir.

X Q. 1137. Character of the ground is another factor?

A. Yes, sir.

X Q. 1138. Now, with reference to one of these factors, namely, the height above ground in wave lengths, will you please refer to Plaintiff's Exhibit 13, tabulations respecting defendant's antennae? You will find that near the bottom of sheet 1. Take antenna No. 1, the height above the ground is 80 feet, and the height in wave lengths is .83 wave lengths, is that right?

A. That is right, that is correct.

X Q. 1139. And No. 2 original, in feet, 80 feet?

A. Yes, sir.

X Q. 1140. Height above ground 1.2 wave lengths?

A. Yes, sir.

[fol. 396] X Q. 1141. No. 2 rebuilt, still 80 feet above the ground?

A. Yes, sir.

X Q. 1142. And in wave lengths, 1.19 wave lengths?

A. Yes, sir.

X Q. 1143. And so on. They are all 80 feet above the ground, are they not?

A. That is correct; all but No. 6; that is 70 feet.

X Q. 1147. If the wave length is different, the height above ground in wave length, assuming the same number of feet, would be different, would it not?

A. Yes.

X Q. 1149. So that, as far as these antennas, with the exception of No. 6, are concerned, the height above ground in feet was not varied?

A. So it appears from the tabulation, yes, sir.

X Q. 1150. And yet the height above ground in wave lengths is an important factor, is a factor, in any event, in the angle of the beam?

A. Yes, sir, because the difference in path of the radiation and the image is dependent to some extent on that.

X Q. 1152. Doesn't it seem reasonable to you that in view of that, if one of the purposes in the design of the defendant's antennas was to control the beam of radiation, control the angle of the radiation, there should have been ~~some~~ more or less definite relation between the height of the antennas above ground and the wave length used?

A. Well, as I think we are agreed, I didn't have anything to do with the design of these antennas, so I can not say that of my own knowledge.

X Q. 1153. I am using "design" in the same sense that you used it in your direct examination.

A. Possibly not to control actually the specific angle, but nevertheless, to obtain radiation at an angle to the horizontal since radiation in the horizontal direction would be of no use.

[fol. 397] X Q. 1154. As I understand it, you obtain it anyway, regardless, within reasonable limits, of the height above ground, do you not?

A. Yes, you must get a tilt to the beam.

X Q. 1155. And differences above the ground with respect to wave lengths, the effect of that, I think you stated a few moments ago, is to vary the angle of the beam?

A. It would have some effect on it; I am not prepared to state in detail what that effect would be.

X Q. 1156. Isn't there another factor that we haven't considered, if it is desired to obtain the greatest propagation possible at any definite angle; in the case of a double V antenna, should there not be a change in the spacing between the two antenna units?

A. The change in spacing—there would be required a very slight change in the spacing between the antenna units; no change at all would amount to being impractical.

X Q. 1157. But in this case, in each instance with defendant's double V antennas, the two separate units are separated an integral number of quarter wave lengths, are they not?

A. Approximately so, and it need only be approximately so, and as I stated this angle is a small angle, and the difference of the hypothenuse to the side of the small angle is extremely small; it is practically negligible.

X Q. 1158. Will you please refer to your answer Q. 393 (R. p. 316). At this point, you were discussing the third Carter patent in suit, and pointing out the passages from the patent which indicated to you that he intended radiation in the plane of the bisector of the angle. In answer to that question, you quoted:

[fol. 398] "'Thus, in Figure 8, each of the radiating units A, B, shown in plan view is provided with a reflecting unit a, b. By means of branched transmission lines, as shown diagrammatically at T, each system is fed cophasally as a result of which an extremely concentrated beam of energy in the plane of the units is transmitted in a direction from the reflecting units towards the radiating units or the reverse, depending upon the relative phase of the standing waves upon the units.'"

Then you stated:

"This again means that the radiation is predominantly in the plane of the wires."

Then you stated again:

"Again, on page 3, line 124",

and again quoting from the patent,

"'By making the phase difference between each of the units equal to 2 pi S divided by lambda, where S is a spacing of each unit measured along the axis, concentrated unidirectional propagation may be obtained in either direction along the X-X axis depending upon whether or not the standing waves on the succeeding units lag or lead each other by the phase difference given according to the foregoing expression.'

"This again teaches the same thing as the other passages which I have read," the last remark being yours.

[fol. 399] Now, as I understand it, and will you tell me whether I am right or not, please, you were there using the fact that Carter said the spacing between the antenna units should be so related to the phasing of them that the result would be expressed by the formula which you quoted, 2 pi S over lambda?

A. Yes, sir.

X Q. 1161. Indicating that he expected horizontal radiation?

A. Well, he so states.

X Q. 1162. And that is the spacing and phasing that defendant uses in its antennæ?

A. Approximately that spacing and phasing. But, as I pointed out with a small angle which the beam goes out in, the difference in spacing is equal to the cosine of the angle of radiation, which, for a very small angle is almost a unity; it departs very slightly from it.

X Q. 1164. In Defendant's Exhibits S and T in deriving the right hand figures, did you not first make the calculations which gave the left hand figures?

A. You understand, I did not make the calculations myself, but I had them made, and I understand those left hand figures were first calculated.

X Q. 1166. And were calculated as a step in arriving at the right hand figures, is that correct?

A. That is correct, yes, sir.

X Q. 1167. Now, you were asked three questions, namely, questions numbers 395, 396 and 397 (R. p. 318), as to whether certain testimony of Mr. Hogan was in your opinion consistent with the passages in the third Carter patent, which you had read, and you stated that in your opinion that testimony was consistent with those passages in that [fol. 400] it indicated the intended radiation in the plane of the antenna.

Now I wish to read to you something else from Mr. Hogan's direct examination, in answer to Q. 79 (R. p. 187), where he said:

"In the operation of a double V antenna such as we have represented by Model, Exhibit 29, the principal radiation of the antenna itself is in the geometric line of the bisector, that is to say, a horizontal beam is produced in so far as the cooperation of the antenna elements themselves are concerned. If a pair of V's of that kind were in space so that no conducting bodies were in their neighborhood to interfere with the direction of propagation, the energy would be concentrated along the geometric line of the bisector, speaking both vertically and horizontally. In practical use the antennas are set up on poles, usually about 80 feet high. Carter says at page 3, lines 58 and 59, that 80 foot poles or masts may be used to support the wires, and

that is a common length. In that case, with the range of wave lengths that is common in short wave transmission over great distances, the wires are, generally speaking, from three-quarters of a wave length to a little over one wave length above the ground. In a case of that kind, if one considers distances a little way beyond the antenna itself and in the direction of propagation, it is not hard to see that following a diagram such as that of Fig. 7, some energy is projected downward to the ground, not directly along the line of the bisector, the geometric line of it. That en- [fol. 401] ergy going down from the end of the antenna is reflected from the ground at an equal angle, and depending upon the character of the ground its phase is changed. The reflected energy combines with the energy radiated from the antenna itself and goes off into space, and the practical result of a set-up of this kind is that the beam from the antenna, instead of being projected along the geometric line, is actually tilted up at some distance from the antenna.''

Do you agree with that statement?

A. Yes, sir, that is what I had to say about the cooperation of the antenna with its negative image, but that is not taught in the third Carter patent, however.

X Q. 1169. Did I ask that last part, Mr. Kelley, whether it was taught in the third Carter patent?

A. I am sorry, Mr. Blackmar.

X Q. 1196. Will you refer, please, to the second Lindenblad patent, Plaintiff's Exhibit 4? With reference to Fig. 2, is there anything shown in that structure, or as described with respect to that structure, which will prevent the formation of standing waves on the antenna wires 2 and 4?

A. My understanding of the specification as a whole, it refers to traveling waves, an antenna of the traveling wave type, and Fig. 2 is one of the theoretical figures in connection with describing the ultimate result, which is, as I understand it, Figs. 3 and 5.

X Q. 1197. Let me read to you, commencing at line 17 on page 1 of this patent, "My antenna consists simply of a pair of conductors which at one end are spaced at the spacing of the transmission line, and are coupled thereto, and [fol. 402] which gradually diverge to a much wider spacing at their other ends." Is that a description of Fig. 2?

A. That could describe Fig. 2, yes sir.

XQ. 1199A. Then commencing at line 32, he states:

"Reflection will cause a standing wave, instead of a traveling wave, and result in radiation sideways from the antenna. Despite this, the radiation in the direction of the antenna is still considerably greater than that obtainable from a simple doublet."

Do you understand that that describes the action of an antenna with standing waves on it?

A. It describes an antenna with standing waves on it, but the statement is not necessarily correct.

XQ. 1200. All right, we may come back to that. Then he goes on:

"However, as a refinement the harmonic radiation may be lessened by reducing the standing waves, and to so do is a further object of my invention."

A. As I understand it, in other words, he is here treating standing waves as something undesirable, he doesn't want them, it is very clear——

XQ. 1202. I hadn't asked a question.

A. I am sorry.

XQ. 1203. With the arrangement of Fig. 2, I think I asked you this before, would there be standing waves on the wires 2 and 4?

A. It would depend on how long the wires 2 and 4 happened to be.

XQ. 1204. And Lindenblad states, and it is pointed out, [fol. 403] that with this arrangement, if they were made long enough to have traveling waves, the spacing at the outer end would be so great as to be impracticable?

A. That is right, that is what he is trying to explain, as I understand it.

XQ. 1205. That is one of the things he is trying to explain.

A. I understand it is the main object.

XQ. 1206. That is your opinion. In your direct examination, in answer to Q. 336 (R. p. 305), when you were discussing Fig. 2 of this Lindenblad patent, you stated that the result "even if the radiation were predominantly along the bisector of the system, would be bi-directional"——

A. Assuming that there were standing waves on the wire.

XQ. 1207. You pointed out as one indication to you that

Lindenblad was proposing to use and was only interested in using traveling waves, his statements as to the use of an impedance matching device, or non-use of an impedance matching device?

A. That was one.

X Q. 1208. You said, as I understood you, in substance, that the absence of an impedance matching device which Lindenblad states as one of his objects is an indication of a traveling wave antenna. That is a correct statement of a portion of your direct testimony, as far as you recall it, is it not?

A. Yes, sir, I am referring to Fig. 2, as I understand it.

X Q. 1209. In other words, you are applying that only to Fig. 2, is that right, that object of the invention? Is that what you meant by your last answer?

A. That is what I meant by my last answer, and I read a whole paragraph on which I commented at the time, and it included not only impedance matching, but also the matter of tuning which, of course, is associated with the standing wave antenna.

[fol. 404] X Q. 1210. Do you remember whether you read this, commencing at line 116 of page 1:

"If the transmission line is short, this may be neglected, but if the transmission line is long, and the antenna is relatively small, so that only a small portion of the energy is radiated, it may prove desirable to employ an impedance matching device between the transmission line and the antenna, as is indicated by the impedance matching unit 16, shown in Fig. 2."

Do you remember whether you read that on your direct examination?

A. I do not recall that I did.

X Q. 1211. What is meant by an antenna being relatively small, so that only a small portion of the energy is radiated?

A. A standing wave antenna.

X Q. 1212. And in the case of Fig. 2 of this patent, if the transmission line is long, that is, electrically long, would it not be desirable to use an impedance matching device, such as 16, I think it is, whether the antenna were a standing wave antenna or a traveling wave antenna?

A. It would depend upon whether or not there was a mismatching of impedances, and as I understand Lindenblad's

teaching in this particular patent, he does do away with that, but I think it would be desirable.

X Q. 1213. In other words, it would not make any difference with an antenna like that shown in Fig. 2, whether you were using it as a traveling wave or a standing wave antenna, so far as the desirability of using an imped-[fol. 405] ance matching device at that point is concerned?

A. An impedance matching device would be apparent for the two cases, because for the standing waves tuning and adjustment would also be desirable.

X Q. 1214. But there would still be the impedance matching device?

A. There could be an impedance matching device, yes, sir.

X Q. 1215. Now, the Lindenblad patent does state that it may prove desirable to employ an impedance matching device under certain circumstances?

A. Yes, sir, in the passage that you just read to me.

X Q. 1216. Now, in Fig. 2, I think you have suggested that if the antenna were long enough it would have substantially only traveling waves on it?

A. Yes, sir.

X Q. 1217. Now, supposing it were, we will say, five wave lengths long, what would it be, a traveling wave or standing wave antenna?

A. In my opinion, a standing wave antenna.

X Q. 1218. What about ten wave lengths?

A. Also standing waves. And you understand when I say that, predominantly so, because in any antenna that is radiating, there are partial traveling waves due to the fact that some of the energy is radiated and can not be reflected back to the source, and therefore the balance, so to speak, of the energy flowing out toward the end which is not converted into standing waves by reflection—since that reflection is reduced by radiation, there will be partial standing waves always, and, as the length of the wires are increased, the opportunity to radiate is greater since there are more—since the wires are more extended, and consequently, as you increase the length of the wires, this partial condition becomes more and [fol. 406] more complete in the direction of traveling waves.

X Q. 1219. As a matter of fact, in standing wave antennas as a result partially of this effect that you are speaking of, the distribution of current along the wire is not truly sinusoidal?

A. There is attenuation along the line.

X Q. 1220. And that affects the distribution of current, does it not?

A. That expresses in one way, the distribution of current.

X Q. 1221. I hand you Defendant's Exhibits CC and DD. Do you know what the units along the lines of the bisector in these diagrams are intended to represent?

A. So far as I know, they are arbitrary units and they are supposed to represent relative power.

X Q. 1222. The individual units are, so far as you know, arbitrary units?

A. I don't recall at the moment just what they are, but I assume that they are arbitrary merely for showing the relative values of power in different directions.

X Q. 1223. Do you know what the concentration, if any, of the relative power in planes other than those of the wires would be in these cases?

A. I have also had prepared a relative distribution of the power in the vertical plane, through the axis of the conductor system (through the bisector of the angle between the wires), that is, one exactly at right angles to this, and if you wish, I can produce it. This is in the plane of the wires.

X Q. 1226. Can you tell me approximately, or in general terms, the nature of that showing that you speak of?

A. Well, it would be a little difficult to describe it without producing it. It is all prepared, and I think that would be a very clear showing. In general, although this is not a complete description of it, I can not remember all of the details, [fol. 407] offhand, but in general, it would show that radiation is not predominently along the axes of the conductor system.

X Q. 1227. That is, in the vertical plane that you speak of?

A. In the vertical plane. There will be another.

X Q. 1228. Is that true of both the four-wave-length wire and the eight-wave-length wire, with this spacing?

A. Yes, sir, as I recall it.

X Q. 1229. Now, with respect to the diagrams that you have before you, Defendant's Exhibits CC and DD, can you state at all what the radiation pattern would be in that plane, if the wires had traveling waves rather than standing waves on them?

A. The wires are open ended, and one diagram is for sides four ways lengths long, and the other for sides eight wave lengths long, and in accordance with Mr. Hogan's interpre-

tation of Fig. 2 of the second Lindenblad patent, it would, of course, have standing waves on them, but if you mean to produce a traveling wave deliberately without consideration of what Lindenblad figures, to simply terminate the wires—is that what you mean?

X Q. 1230. That could be done, by a termination resistance?

A. Yes, but that would no longer be the Lindenblad antenna. I would not say what they would be, except that one of the opposite directions here, the radiation, say, to the rear, would be considerably reduced, and it would be mainly in the other direction.

X Q. 1231. To the left, as you look at the diagram, of the center vertical line of the diagram?

A. The left of the center vertical line of the diagram, that is right, and the radiation would be confined largely to the right hand section.

[fol. 408] X Q. 1233. And would not the pattern be, in general form, approximately similar to the right hand half, for example, of that pattern?

A. I would expect it to be quite similar to it.

X Q. 1234. On those exhibits, is there sideways radiation?

A. Yes, there is quite a little sideways radiation.

X Q. 1235. How are you interpreting my question as to what I mean by sideways radiation?

A. Well, I would interpret it to mean radiation other than on the axis—or the direction of the axis of the conductor system.

X Q. 1237. In discussing this patent, in answer to Q. 329 (R. p. 303), after reading a portion commencing at line 47 of page 1 of the patent, you stated:

"To paraphrase what he states in this passage, he recognizes that he must have the antenna long enough to consume a very large part of the energy."

In that statement you were assuming, weren't you, that the antenna was to be a traveling wave antenna;

A. Yes, and by "consume a very large part of the energy," I meant that a large part of the energy would be radiated.

X Q. 1238. Are you familiar with the Marconi beam type of antenna or the parabolic reflector type?

A. I have had no experience with them, sir.

X Q. 1239. Have you any idea what has to be done with those antennas to tune them?

A. I don't know the details, if that is what you mean, of tuning.

X Q. 1240. Do you know whether it is an easy and simple thing to do or not?

A. I believe it would not be very easy.

[fol. 409] X Q. 1241. It would not be as easy, for example, as tuning a standing wave antenna of the type of Fig. 2 of this patent, would it, assuming that that is a standing wave?

A. Assuming that it is a standing wave antenna, since you would only have to tune in one place, it would be easy to that extent.

X Q. 1242. And if you changed the wave length applied to such antenna, the returning would not be very difficult, would it?

A. No, sir, providing in the design of the tuning adjustment, provision was made for that.

X Q. 1249. Let us confine ourselves then to Fig. 2 of the second Lindenblad patent. Assuming that the antenna is tuned in Fig. 2 so as to be, say, 10 wave lengths long—I may be using tuning in a very popular sense, but with these long wires, that is more or less correct, isn't it?

A. Yes, sir, I agree to that.

X Q. 1251. And you change the frequency so as to make the wave length longer, lessen the frequency; now, if that wave length were in the neighborhood of ten per cent longer, the antenna with its prior adjustment, would be nearly tuned to the new frequency, would it not?

A. As only respects tuning?

X Q. 1254. That is all I am talking about, tuning?

A. Yes, that is right.

X Q. 1255. Speaking of tuning, and only tuning, does this statement, on page 4 of the First Lindenblad patent, apply generally to the type of antenna shown therein, and in the second Lindenblad patent, commencing at line 10:

"This tuning need not be great in range, though the antenna structure will cover a great wave length range, be- [fol. 410] cause the adjustment can be made for a different number of half waves in length whenever necessary to accommodate a desired wave length."

A. There is an added element in that passage that you read to me, referring to, as I understand it, adjustment other than tuning, and if we confine our attention to tuning, as you suggested, this would be true of single wire or any standing wave antenna. It could be retuned, if that is what you mean—it could be returned—any standing wave antenna could be retuned.

X Q. 1256. And if it has two or four wires, that process is easier, is it not, than in a standing wave antenna of the type of the Marconi beam antenna, or the parabolic reflector type?

A. Well, you have multiplicity of tuning in the latter case, but I am referring to tuning in general since I understand that is what we are speaking of. If you tune a standing wave antenna to one frequency, it is, of course, not a very difficult matter, provided you have made provision for it, to tune the same antenna to a different frequency.

X Q. 1257. But with an antenna that requires a large number of individual radiators, that is quite a little harder, isn't it, than one that requires only two or four?

A. By virtue of the fact that you have more places to tune.

X Q. 1258. And in the case of an antenna like the Marconi beam, you have a great many places to tune, have you not?

A. Yes, of that particular type, yes, sir.

X Q. 1259. In fact, there are 30, maybe 60, individual radiators?

A. Depending on how many radiators you have because you have to tune each individual one.

[fol. 411] X Q. 1260. Now, you said a few minutes ago that you had charts showing the radiation pattern in the vertical plane comparative to those showing horizontal radiation in Defendant's Exhibits CC and DD. I think you offered also to submit them to me?

A. Yes, sir, I did.

X Q. 1262. Would you mind doing so?

A. I will be very glad to. I would rather refresh my memory on them.

X Q. 1263. These charts that you have handed me are such charts?

A. They are such charts, yes, sir.

Mr. Darby: With Mr. Blackmar's permission, I offer the charts in evidence that Mr. Blackmar has called for the production of. I offer the chart in the vertical plane of the four-wave-length antenna in evidence.

The Witness: Vertical plane through the bisector of the angle or the axis of the conductor system.

Mr. Darby: Through the bisector of the angle or the axis of the conductor system.

(Marked Defendant's Exhibit FF in evidence.)

Mr. Darby: And I offer in evidence chart in the vertical plane through the bisector of the angle or the axis of the conductor system for eight wave lengths.

(Marked Defendant's Exhibit GG in evidence.)

X Q. 1265. In the course of your direct examination, Mr. Kelley, I wasn't sure whether you were making a distinc- [fol. 412] tion between the terms "radiate" and "propagate", were you?

A. Not intentionally. I did not mean any real difference; I was using the terms interchangeably.

X Q. 1267. In Q. 326 (R. p. 300), you stated that you agreed substantially with the statement made on page 2 of the second Lindenblad patent, Plaintiff's Exhibit 4, commencing at line 93, the place where Lindenblad refers to the image in the ground; and two pages later, you also stated that you agreed substantially with another statement which Mr. Darby read to you, respecting the subject of the image. Would you mind telling me what you meant by "substantially" in these answers?

A. Taking them up in order, the reason I had it "substantially" is because while an antenna such an described on page 2, line 93, the passage which you directed my attention to, where he says that it would function exactly the same as if the two wires were present and in phase opposition above the earth, as they would with one-half of the system removed, and the other half being constructed above the earth and cooperating with its image, the reason I used the qualification "substantially" is this: That in theory, assuming a perfect ground, that is true, and that that is the teaching of the art, and that one would naturally make the step that Lindenblad does in going from two wires excited in phase opposition to the structure where one-half is omitted and the image in the ground furnishes the other half of the system, that is the phase opposition and standing waves, if there are standing waves in the half of the system above the ground. That is true in theory and is the teaching of the art.

With imperfect grounds, it is not quite true, but the teach-

[fol. 413] ing is there nevertheless, and in that respect, I agreed with Lindenblad in both his statement in the patent to which my attention was directed, and also the quotation from a letter of Lindenblad's which was read to me.

X Q. 1268. And does your answer cover wherein you disagree with him?

A. Yes, I think it does. I said that it is true in theory, and it is also an accepted thing in practice in determining what the radiation shall be at a distant point, as a first step, but that imperfect ground might alter it, or would alter the theory in certain respects. You see, what I am trying to do is to make a distinction between the teaching involved and what would actually happen, and in that connection, that the naturalness of this equivalent between the two wires above the ground, as being equivalent to a single wire in a vertical plane above the ground, removing the other wire, but allowing the ground image to take its place. That is a natural step, but due to imperfect ground in actuality this is not always achieved.

X Q. 1270. Now, do you know in general the radiation pattern in free space of a wire four wave lengths long, considering only the principal lobes of radiation?

A. Well, the principal lobes will be inclined toward the wire in both directions, the angle,—I am trying to remember—at an angle of something like 50 degrees, they will be inclined at an angle perpendicular to each other.

X Q. 1273. That is easily ascertained if you wish to ascertain it?

A. Yes, it can be computed.

X Q. 1274. Could you indicate roughly on this piece of paper that I am handing to you the radiation pattern in free space of a four-wave length wire, assuming the line [fol. 414] that I have drawn there as the wire, and taking it in a single plane?

A. Well, it would be very rough.

X Q. 1275. Certainly; I am not asking for accuracy, I am asking for qualitative, not quantitative results.

A. Just the principal lobes?

X Q. 1276. Just the principal lobes, that is all I think we need to consider.

A. This is the general nature of it, rather roughly drawn. (Witness handing paper to counsel.)

X Q. 1277. I will write below this, Mr. Kelley, "Fig. 1." There is already written above it, "4 lambda wire,"

"lambda" being the common symbol for wave lengths, is that correct?

A. That is correct.

X Q. 1279. I will also write above "4 lambda wire" the words "free space" because I understand that the pattern that you have drawn is the pattern in one plane of the wire in free space.

A. Yes, sir, the plane including the wire; that is correct.

X Q. 1281. Now I will draw another line below that on this same sheet, which I will have to describe to you as representing a side view of a V antenna, each wire of which is four wave lengths long and the angle of which is the correct angle to secure the maximum radiation along the bisector of the structure. As a structure, is that clear to you, what I am describing?

A. Yes, sir, but now we are getting into things that I would much rather have computed because rough diagrams like these may be misleading. I would be very glad to have that computed in accordance with your instructions.

X Q. 1282. You are not willing to draw qualitatively on here the general nature of the radiation from such a struc- [fol. 415] ture in free space.

A. It is not a question of willingness, Mr. Blackmar, I want to do everything to help you, but it is a question of being accurate, and I certainly do not want to do something offhand which may lead to an incorrect conclusion.

X Q. 1283. Supposing I take the responsibility for the moment, then, of drawing the pattern and I ask you whether you think it is reasonable, and we will see if we can reach it in that way, and if not, we will drop the subject, perhaps. I hand the sheet to you, having drawn with respect to the wire at the lower left-hand corner of the page two lobes by which I intended to represent the main or principal radiation from such a wire in the plane of the wires in free space.

A. This being a vertical section?

X Q. 1285. Being a side view of a V.

A. Well, with the reservation that I made previously it appears reasonable.

X Q. 1287. I will mark that "Fig. 2" and we will assume that free space applies to that also, since it is under it.

A. That would have to be free space.

X Q. 1288. Above it I will put "V" in quotation marks, "with four lambda wire (correct angle)."

A. Well, I don't know what you are assuming by the correct angle.

X Q. 1289. What I mean by "correct angle" is the correct angle of the V to secure the maximum radiation in free space along the bisector of the wires, in accordance with the teaching of the third Carter patent.

A. Very well, I agree.

X Q. 1291. Now, to the right of Fig. 2 I will draw another wire or another line, marking it "Fig. 3", and I would like [fol. 416] to ask you to indicate on there what the effect is of placing the antenna of Fig. 2 above perfect ground, which I have indicated below the line representing the V antenna, assuming the radiation pattern to be as it appears in Fig. 2 without ground. Do you know what the effect of ground is upon such a radiation pattern?

A. I have already explained that.

X Q. 1293. All right; will you illustrate it now, please?

A. Very roughly.

X Q. 1294. Merely qualitative is understood?

A. Yes.

X Q. 1295. And that is over perfect ground, as I understand it?

A. Yes.

X Q. 1296. Still, to the right of that, I have drawn another line and marked it "Fig. 4", below which I have indicated ground, and I ask you to assume that that line represents the same as is represented by the main lines in Figs. 2 and 3 and also to assume that ground in Fig. 4 is practical ground, for instance, such as there is at Sayville. Can you indicate qualitatively the results in that case as compared with Figure 3?

A. Well, I believe it would be fallacious to represent that even qualitatively because different ground conditions are subject to computation, and, as I mentioned when we started out on these series of questions, it might be very misleading not to compute the results; that wrong conclusions might be drawn from them.

X Q. 1297. Going back to Fig. 1; to the right of that I have drawn another line, writing "Fig. 4" below it, that line representing, as in Fig. 1, a straight single wire four wave lengths long; I have also indicated below that wire a symbol for ground, and I ask you whether or not you can indicate [fol. 417] qualitatively the effect of this ground, considered

as perfect ground, upon the radiation pattern shown in Fig. 1?

A. There again, Mr. Blackmar, if you please, I would much rather do that through computation. I will be very glad to have it done for you.

X Q. 1299. And I suppose your answer would be the same if I asked you to make the same illustration for Fig. 5, which is the same as Fig. 4, except that ground is practical instead of perfect?

A. Yes, sir; you mean by that, well, for instance, the ground at Sayville or something comparable to it be taken?

X Q. 1301. I thought taking it qualitatively it might be possible to avoid the necessity of calculations because this was explained to me by sitting down beside somebody in a few minutes as to qualitative effect.

A. It is very easy, as I stated before, to draw misleading conclusions, since all of these things are subject to computation it seems to me that is the proper way to handle it.

Mr. Blackmar: I ask that the sheet of sketches be marked for identification.

(Marked Plaintiff's Exhibit 36 for Identification.)

X Q. 1304. Referring to Defendant's Exhibit F, is that intended to represent wires of a certain length with respect to the wave length?

A. It is not so indicated on Exhibit F.

X Q. 1305. How about Exhibit G?

A. Judging from the radiation patterns which are on Exhibit G, the sides would be four wave lengths long.

[fol. 418] X Q. 1306. And is that the length of the wires that is intended to be indicated in Exhibit G?

A. I should say so, yes, sir.

X Q. 1307. As to Exhibit G, roughly what is the relation of the spacing between the open ends of the wires of Exhibit G with respect to the length of those wires, about one and four-fifths, something of that kind, roughly?

A. Well, the spacing is greater than the length of either one of the wires and less than twice the length of the wires, something in the middle.

X Q. 1310. I thought engineers always calculated quickly when they had angles like approximately twice 60 degrees, so that they could picture the sines, cosines and tangents.

A. It depends where you are, and when you are trying to

be as careful as I am trying to be you won't make any snap answer like that.

X Q. 1311. I say, it is approximately somewhere between one and a half and two, scaling it with your eye.

A. Yes, that is what it appears to be, but I want to be as accurate as I can.

X Q. 1312. In any event, the spacing at the outer ends of these wires isn't in the neighborhood of one-fifth of the length of the wires, is it?

A. Not at all.

X Q. 1313. And you understand that is what is stated as a suggestion in the second Lindenblad patent, do you not?

A. I want to look at it because that is not the only thing it says.

X Q. 1315. It also says, for example, at page 2, line 120, that "the length of each antenna section should be of the order of magnitude of five to ten waves long".

A. That is of each section in Fig. 3 or 5.

[fol. 419] That is the only one that is more than one section, and "each" would apply only to Figs. 3 and 5.

X Q. 1316. That is the way you construe that?

A. I think that is what it says. The other thing that occurs in this passage in respect to the relation between spacing and length of the wires, while he mentions ⅕ as spacing compared with the length of the wires, there is also included: "while variable over a great range."

I am sure that I do not know what he means by that.

X Q. 1317. It also says that it should be in the neighborhood of one-fifth of the length?

A. Yes, but he also adds the other. So I am not sure what to draw from that.

X Q. 1318. Now, when this Chart, Defendant's Exhibit G was prepared, you understood, did you not, that it would show the absence of radiation in the direction of the bisector between the wires?

A. A substantial absence of radiation, yes, sir.

X Q. 1321. Coming to the third Carter patent, let us start with a single long wire in free space. Suppose it were five wave lengths long; as I understand it, the radiation pattern of that wire in free space would be what is indicated in Fig. 1-b of this patent, except that, of course, the radiation is conical, whereas the figure is a plane figure?

A. Yes, sir, Fig. 1b shows the field type radiation pattern which would be given by computing from the Abraham

formula where n is equal to 10, five wave lengths long, being 10 half wave lengths, and that is from a single wire; and in order to visualize the whole thing in space it is necessary, as you suggested, to consider this rotated around in all directions.

[fol. 420] X Q. 1322. Now, if you take two of these wires, still considering free space and place them at an angle with each other, which is twice the angle alpha as indicated in Fig. 1b, so that the lobes of radiation along the bisector of that angle will add, do you understand the structure that I mean by that?

A. I believe I do, sir.

X Q. 1323. That is like, for example, Fig. 2a of the patent, assuming that the wires of that are five wave lengths long, and the correct angle alpha is used in that case?

A. Yes. Do you mean by alpha the angle of principal radiation determined from the Abraham formula, where you consider the lobes which are most important?

X Q. 1324. I mean the angle alpha as indicated in Fig. 1b of the third Carter patent?

A. Yes, sir, that is right.

X Q. 1325. What happens in that case to the principal lobes of radiation along the bisector of the angle?

A. Speaking from a theoretical standpoint, that is, assuming you can make this angle just exactly right, that would mean that in that direction, that is, along the bisector of the angle, and in the plane of the wires, one of the lobes from one of the wires would add perfectly with a corresponding lobe of the other wire; there would also be in the diametrically opposite direction, a similar addition.

X Q. 1327. What happens with respect to the main lobes in the directions of the bisector of the angle? In one direction, the forward direction, they add, and also that the same effect occurs in the rear direction?

A. In the rear direction, and there will still be principal lobes which will not be in that direction at all.

[fol. 421] X Q. 1328. We are both assuming that the wires are fed in phase opposition, are we not?

A. Why, I am assuming that, yes, sir.

X Q. 1329. Now, that takes care of two of the main lobes from each wire, does it not, the radiation along the bisector line?

A. Yes, sir, that is right.

X Q. 1330. Will you tell me what happens to the remaining two principal lobes with respect to each wire under those circumstances?

A. The remaining two principal lobes radiate off in odd directions which are not on this same line.

X Q. 1332. The other two lobes do not cancel each other, is that correct?

A. No, sir, they form an X.

X Q. 1333. Instead of placing the two five wave length wires at this angle, suppose they are placed parallel to each other, still fed in phase opposition, and staggered with respect to each other, in accordance with Fig. 4 of the first Lindenblad patent, except that the spacing between the wires is made correct for complete addition. I understand that you said that that could be done. A. Yes, sir, that can be done.

X Q. 1334. And do you understand what I mean by that structure?

A. Yes, sir, you are assuming that we forget for the moment the wrong instructions of Fig. 4 of the First Lindenblad patent, and assume the correct spacing.

X Q. 1335. Assuming the correct spacing, that is right?

A. Yes, sir.

X Q. 1336. And that they are staggered?

A. Yes, sir.

X Q. 1337. There is no question about the correctness of the stagger in Lindenblad, as far as you understand, is that correct?

[fol. 422] A. Well, it can't be taken alone, the stagger by itself doesn't mean much unless the correct spacing is also adhered to.

X Q. 1338. With that structure will you please tell me what the effects are on the four main lobes from each of the wires as to the radiation pattern of the antenna?

A. You mean just in a general way?

X Q. 1339. Yes.

A. Generally speaking there would then be appreciable cancellation of the two oppositely directed lobes and the conjugate set of lobes would add perfectly in the direction of maximum radiation, in the direction of the principal radiation.

X Q. 1340. You spoke of appreciable cancellation, I think, of two of the lobes?

A. Yes, sir.

X Q. 1341. How would that compare with the arrangement that we spoke of for the V antenna with respect to the lobes outside of the bisector line? Is it greater or less than in that case?

A. Offhand I would say that it might be less because in the case with wires formed at an angle to one another, the other principal lobes of radiation, those that do not line up along the bisector of the angle between the wires, go where they will, so to speak, in a deliberate attempt to cheat cancellation. Whatever happens as to miscellaneous addition, taking into account phasing and difference of path of travel, and so on, without having actually gone into that in detail, my impression would be that the cancellation ought to be more complete in the parallel wire arrangement.

X Q. 1342. It is really a little more than an impression, isn't it, because in the parallel wire arrangement the unused lobes, so to speak, are in the exact direction to cancel each other, aren't they?

A. Yes, in the plane of the wires. You understand, Mr. [fol. 423] Blackmar, that that is a pretty thin thing and a loop has some thickness to it to be useful. I think we can agree that in a general way there would be substantial cancellation.

X Q. 1343. So that with the V arrangement there is, as far as main lobes are concerned, more sideways radiation than with respect to the parallel wires?

A. That is my impression.

X Q. 1344. Will you agree with me that nevertheless the power gain in the case of the V antenna correctly located with respect to angle is greater than the power gain of two parallel wires arranged at the proper stagger and spacing?

A. There are all kinds of definitions of power gain and that is something that I would not answer offhand.

X Q. 1345. Do you have any objection to this definition of power gain: The ratio of the power projected in the desired direction from the antenna under consideration to that projected from a half wave di-pole when supplied with the same input power?

A. I would not agree to it offhand because I understand that you are assuming that all one needs to do then is to take these theoretical diagrams and attempt to show from that that it is so. The only reliable way to consider it, it seems to me, is experimentally, in other words, what actual results one gets.

X Q. 1346. Will you turn, please, to your answer to Q. 356 (R. p. 309). At that place you were comparing, I believe, defendant's antenna No. 8 with the third Carter patent in suit and there is a statement there that I think may bear an implication which you did not intend. I will read therefrom:

"This upper left hand figure represents the theoretical radiation,"

[fol. 424] That was with respect to Defendant's Exhibit S, I think.

"or in other words, the radiation in free space from the V of defendant, at an angle of 45 degrees, whereas the radiation in free space, using the angle recommended by Carter of 50 degrees, gives a somewhat greater theoretical radiation in free space, but it is not usable."

That does not mean that the 50-degree angle of Carter is not usable, does it?

A. No, it doesn't mean that. It means that the theoretical radiation is not usable as yet.

X Q. 1347. We spoke this morning of the desirable angle of radiation with respect to the horizontal for the purpose of radio communication or radio signalling and I think you included the angle of ten degrees as one that might be desirable.

A. Well, a range of angles. I said ten to fifteen degrees.

X Q. 1349. Have you any real idea as to what the best angle is, or can't that be stated?

A. I don't think it can be stated.

X Q. 1350. Will you please refer to Defendant's Exhibit S now, with defendant's antenna No. 8 as compared to an antenna with the angle of 50 degrees, what would be the relative effectiveness, according to this chart, of those two antennas at an angle ten degrees above the horizontal, approximately?

A. The curve is very steep in that portion of the lobe. It would be very difficult to determine it accurately. It is pretty difficult to see there is any difference. It would be about the same.

[fol. 425] X Q. 1354. And if that were the desired angle of radiation, so far as this chart shows, there would not be any advantage in using an angle of 45 degrees rather

than one of 50, would there, within the range of approximately that we spoke of?

A. Approximately, no.

X Q. 1355. In discussing this subject of relation between the angle used between the wires and the angle of radiation, of propagation, you stated, in answer to Q. 361 (R. p. 311), which read:

"Now, will you state whether or not the same is true with the other antenna of the defendant, which is concerned with this question, defendant's antenna No. 2?

"A. Yes, sir."

Again you were asked:

"Q. 366. Are these diagrams that you have referred to with reference to defendant's antennas Nos. 8 and 2, are they typical and apply equally as well, differing quantitatively, of course, to all of defendant's antennas?

And your answer to that question was:

"Yes, they are typical."

In the first place, by all of defendant's antennas, you understood all of the V's, I assume?

A. Yes, sir, that is correct.

X Q. 1358. Now, the charts referred to in that question were Defendant's Exhibits S and T, is that correct?

A. That is correct.

X Q. 1359. Will you please look at Defendant's Exhibit T, and again assume that the desired angle of radiation is ten [fol. 426] degrees from the horizontal?

A. Yes, sir.

X Q. 1360. Which of those two antenna systems shown in this diagram would be more effective at that angle?

A. The upper right hand one would be slightly more effective than the lower diagram. The upper right hand one would be slightly more effective at ten degrees.

X Q. 1361. Yes, about how much?

A. About two per cent. more.

X Q. 1362. Now, in that case, the difference between the angle of Defendant's antenna No. 2 (speaking of the angle between the wires now) and the angle determined according to the teaching of the Carter patent is .6 of a degree, is that correct?

A. Yes, sir, that is the difference in the angle.

X Q. 1363. Now, as I understand your answer to Q. 366, the same effect would be obtained qualitatively, although not quantitatively even if the angles were just the same?

A. Well, there would be a difference.

X Q. 1365. Between two antennas of the same angle?

A. No, no, not with the same angle—will you please state the question again?

X Q. 1363. (Repeated by the Reporter.)

A. I am afraid I will have to ask you to explain what you mean, because I don't know what angles you are referring to, that is, to what you are actually referring.

X Q. 1364. In your Q. 366, you were asked:

"Are these diagrams"—that is Defendant's Exhibits S and T—"typicaly and apply equally as well, differing quantitatively, of course, to all of defendant's antennæ?

[fol. 427] I understood from that that you mean that all of defendant's antennas utilized the angle which gave them greater radiation at some angle from the horizontal, in spite of some apparent sacrifice with respect to radiation along the bisector of the angle?

A. Not necessarily, I was there referring to the fact that in depending upon radiation at an angle to the horizontal, such as shown in the right hand figures of these exhibits was a departure from the teachings of the third Carter patent, wherein it states that the radiation should be in the plane of the wires along the bisector. That was the meaning of my answer.

X Q. 1365. I think I will have to go back over the few preceding pages of the record under those circumstances. The discussion of these exhibits started in connection with Q. 356 (R. p. 309), where you were asked to explain the diagrams of what is now Defendant's Exhibit S. It commences even a little before that. You said there that an angle of 50 degrees between the wires is the angle that would have been used had the instructions of the third Carter patent been followed, where actually the angle is 45 degrees.

"In defendant's structure, it is 45 degrees. The reason for this being that by using this angle different from the Carter, or the angle recommended by Carter, in his third

patent, a larger lobe of radiation is obtained when an actual structure cooperating with the ground, its image in the ground, radiates at an angle inclined to the horizontal.

"The radiation, the ultimate objective, so to speak, that which goes out to the receiving station, is greater by using [fol. 428] the angle of 45 degrees with the same length of wire than it is by using the same V, but an angle of 50 degrees, as is recommended in the third Carter patent.

"It was done at an apparent sacrifice as will be seen by comparing the two left hand figures."

Then you go on discussing them further.

Then you state:

"In other words, the upper left hand figure, where the angle is 45 degrees and corresponds in defendant's antenna, the radiation is somewhat less in this direction than it is for the angle of 50 degrees in that same direction, but for the radiation which actually goes out, that is, the ultimate usable radiation, is greater as seen by comparing the two right-hand patterns where the distance numerically is 31 for the upper right-hand pattern and about 28.6 for the lower one.

"Q. 358. If it has been suggested in this case, that by defendant's departure from the angle recommended by the Carter patent in suit by five degrees, the defendant has sacrificed anything in the efficient propagation of its waves, do you agree or disagree with any such suggestions?

"A. I disagree.

"Q. 359. And does this chart which you have been describing illustrate the reason for your disagreement?

"A. Yes, sir, because the apparent sacrifice is turned into a real gain.

"Q. 360. And when you say 'apparent sacrifice', what do you mean? Do you mean apparent from theoretical con- [fol. 429] siderations or from practical considerations?

"A. I mean from practical considerations.

"Mr. Darby: I now offer in evidence the chart referred to by the witness.

"(Marked Defendant's Exhibit S in evidence.)

"The Court: Did the patentee limit himself to that 50 degree angle, or was that just a suggestion?

"The Witness: The patentee gives the proper angle for a given length of side in electrical length in Fig. 12 of the specification, and in this Fig. 12, the angle 50 degrees corresponds to the one that he draws a curve for, so that that is the angle which he says should be used.

"Q. 361. Now, will you state whether or not the same is true with the other antenna of the defendant, which is concerned with this question, defendant's antenna No. 2?

"A. Yes, sir.

"Q. 362. Have you made a similar pattern and comparative diagram showing what the radiation pattern would be in direction along the bisector of the angle of the conductors in the plane of the wires, at an angle of the V of 35 degrees such as employed in antenna No. 2, and what it actually is and what it would be in both instances if the angle of the V were 35.6 degrees?

"A. I have had such a diagram made.

"Q. 363. And does the same relation that you have described with reference to Defendant's Exhibit S apply to defendant's antenna No. 2?

[fol. 430] "A. The same considerations apply to antenna No. 2, yes, sir.

"Q. 364. And are the same results obtained?

"A. The same results are obtained, yes, sir.

"Q. 365. And do you draw the same conclusions?

"A. Yes, sir, the two upper diagrams here correspond to defendant, and the two lower, if the angle from Fig. 12 of the third Carter patent were used.

"Q. 366. Are these diagrams that you have referred to with reference to defendant's antennas Nos. 8 and 2, are they typical and apply equally as well, differing quantitatively, of course, to all of the defendant's antennae?

And your answer to that was:

"Yes, they are typical."

Do you wish to change that last answer, Mr. Kelley?

A. Not at all. When I made that answer I was referring to the fact that radiation from all of the defendant's antennae, that is, the ultimate radiation is at an angle to the horizontal, and therefore departs from the teaching of the third Carter patent. With reference to antenna No. 8 and antenna No. 2, that is very specific. The general idea that

there is radiation not in the plane of the wires but at an angle to the plane of the wires was what I had in mind in replying to question No. 366 when I said that these were typical.

X Q. 1366. But that subject had not been discussed in the preceding two or three pages that I read to you, had it?

A. Oh, yes, sir, I think it was. The reference is actually [fol. 431] to the diagrams for two specific antennae, and in the case of those two they were plotted and showed what I was describing.

X Q. 1367. And they both showed a gain in that maximum tilt angle, did they not?

A. That is right, but when I answered the question to which you referred, I had no such diagram to go by; I had to make a general statement, and what I had in mind was the radiation at an angle which was not in the plane of the wires.

X Q. 1368. Yet you said that the diagrams that you had before you were typical of the other antennae?

A. Yes, sir, and they were with respect to this angle of inclination.

X Q. 1368A. And were they typical with respect to the thing you had been discussing on the last two or three pages, namely, that the radiation at the angle was greater in the case of defendant's antenna than it would have been with the antenna of the Carter angle?

A. I do not know; the only two that were plotted were Nos. 2 and 8, and they happen to be the two that Mr. Hogan referred to in his testimony.

X Q. 1369. Are they the only two that he referred to in his testimony?

A. To the best of my recollection they were the only two into which he went into in any detail to speak of.

X Q. 1370. Do you now know whether there would be any difference if similar patterns were made for the other antennas of the defendant?

A. They would all radiate at an angle; I do not know specifically what the relation would be, making the same comparison as shown in Exhibits S and T.

X Q. 1371. Would they all be qualitatively the same kind, [fol. 432] give you more radiation at an angle than you would get with the Carter angle?

A. I wouldn't say that; I do not know.

X Q. 1372. Some of them may be less?

A. It is possible; I said I do not know.

X Q. 1373. And with respect to the distinction between the defendant's antennae radiating at an angle and what is in the Carter patent, I call your attention to the fact that each of these diagrams you had before you, Defendant's Exhibits S and T, showed at the bottom an illustration of what the radiation would be upon a V antenna with a Carter angle when it is over ground?

A. No, sir, Carter does not teach that.

X Q. 1375. Is that illustrated on this diagram or chart?

A. The ground is added in the lower right hand figure, yes, sir.

X Q. 1376. In other words, the lower right hand figure does show what the radiation of a horizontal V antenna with the Carter angle if placed over the ground would be, is that correct?

A. Yes, that is correct, over ground.

X Q. 1377. I think you said this morning that practically all antennas of this type are placed over ground.

A. Yes, sir, we said that practically all antennas are placed over ground, but when we wanted radiation at an angle Carter tells us to tip the whole structure to radiate at that angle.

X Q. 1378. I hand you two sketches marked respectively 1 and 3; I understand that the sketch marked 1 has been plotted to represent the power distribution in the vertical plane for a single V antenna whose wires are 8.14 wave lengths long, the included angle between the wires being 34.66 degrees, the power distribution being illustrated in free space. Does that look like a reasonable plot of power distribution of that character?

[fol. 433] A. It looks reasonable, but one cannot draw quantitative conclusions from it without checking it.

X Q. 1379. And referring to the diagram labeled No. 3, I understand that has been plotted to show power distribution in the vertical plane of the same antenna assuming that it is mounted over perfect ground, does that look like a reasonable change from one to the other, disregarding quantitative values?

A. There is a rather important detail missing on this sketch No. 3.

X Q. 1380. What is it?

A. Namely, the height of the antenna above the ground.

X Q. 1381. What height did you assume with respect to Defendant's Exhibits S and T for the antenna utilizing the Carter angle?

A. I assumed that the height was the actual height of the defendant's No. 8.

X Q. 1382. I am told that in that case not only was it over perfect ground, but it was over perfect ground at the same height as defendant's antenna No. 2 rebuilt.

A. May I make that notation on the sketch?

X Q. 1384. Certainly. With respect to the chart marked 3, you may note on it that it has been assumed that the antenna is 80 feet above ground, in other words, 1.19 wave lengths above ground. I also hand you two more similar charts marked 2 and 4. I understand that these charts are plotted to represent the same characteristics except that the angle between the wires, the included angle, is 40 degrees, which is the included angle of defendant's antenna No. 2 rebuilt according to the stipulated data. There is one thing I wish to mention in connection with the charts and that is that antenna No. 2 is a single V and that these diagrams show the radiation only on one side of the antenna system. [fol. 434] I am going to ask you, Mr. Kelley, some time between now and a few days from now, possibly, to check those diagrams.

A. I shall be very glad to do so.

X Q. 1389. Is there any further information that you need?

A. I don't think of it at the moment, but if I do, I am sure you will be glad to give it to me.

Mr. Blackmar: I offer the chart referred to above, and marked No. 1, for identification.

(Marked Plaintiff's Exhibit 37 for Identification.)

Mr. Blackmar: Similarly the chart marked No. 3, for identification.

(Marked Plaintiff's Exhibit 38 for Identification.)

Mr. Blackmar: Similarly chart marked No. 2 is offered for identification.

(Marked Plaintiff's Exhibit 39 for Identification.)

Mr. Blackmar: And similarly the chart marked No. 4, also for identification.

(Marked Plaintiff's Exhibit 40 for Identification.)

X Q. 1391. You stated, in answer to Q. 405 (R. p. 324): "Defendant's antennæ operate on a different principle from that taught by the third Carter patent in suit". Will you please explain what you meant by that answer?

A. I did explain this in my direct testimony, but if you would like to have me repeat it, I will be very glad to do so.

[fol. 435] X Q. 1392. No explanation appears in the answer in its present form, nor any reference to anything else in that answer. In general what were you referring to?

A. I was referring to the teaching in the third Carter patent, and I pointed out, as I recollect, something like eleven instances where it is taught that radiation is to take place in accordance with the third Carter patent teaching along the bisector of the angle formed by the wires, and when those wires are in a horizontal plane, that the radiation is to take place in a horizontal direction in the plane of the wires, and that when it was desired to radiate at an angle other than the horizontal, the whole structure is tipped after the fashion of aiming a rifle, the aim being along the bisector of the angle.

X Q. 1393. I take it that was what you also meant in answer to the next question, when you said they functioned differently.

A. Yes, sir.

X Q. 1394. Is that correct?

A. That is correct.

X Q. 1395. Is that the only difference in principle that you referred to in your answer to Q. 405?

A. Different angles are used in the antenna structures of defendant as well.

X Q. 1396. Does that make them operate on a different principle, in your opinion?

A. Yes, sir, because striving to make the angle such that radiation will be along the bisector of the angle is a different object than the one where the angle is changed for another purpose.

X Q. 1397. Of course, that statement, "different in angle" applies to only some of the defendant's antennæ, does it not?

A. I think it applies to all of defendant's antennæ to a greater or less extent. The chart showing the distribution [fol. 436] of the angles is quite an irregular curve and some are nearer and some are farther away.

X Q. 1398. Some of them are within a few hundredths of a degree, are they not, of the angle taught by the Carter patent? A. Some of them—three of them, I believe, are fairly close to the angle shown on Fig. 12 of Carter.

X Q. 1399. In fact, they are as close as you can determine on that curve, aren't they?

A. Well, considering the scale or magnitude of the drawing, yes, sir.

X Q. 1400. Considering the width of the line, for example, that makes the curve?

A. Yes, you cannot show differences on that chart as small as that.

X Q. 1401. Is there any other reason why defendant's antennæ function differently from the antenna as taught by the third Carter patent in suit other than taking into account the ground reflection?

A. And the difference in angle.

X Q. 1402. The same answer applies to that?

A. The same answer applies to that, yes.

X Q. 1403. Is "horizontal directivity", an ordinary term in the radio art today?

A. Well, I don't know whether there is such a loose definition or expression, I could not say.

X Q. 1404. Now, going back to the previous subject, my attention has been called to the fact that you have not said whether ground effects and differences in angle are the only things that might make defendant's antenna operate on a different principle from that taught in the third Carter patent?

A. I believe I answered that with a "yes".

X Q. 1405. Those two things are the only things?

A. Yes, sir.

[fol. 437] X Q. 1406. Now, suppose you were at a receiving station in San Francisco or in Europe, receiving signals from Sayville, Long Island?

A. Yes.

X Q. 1407. Would you be able to tell, at the receiving station, at what angle from the horizontal those signals were sent out?

A. Not necessarily.

X Q. 1408. At the receiving station itself, could you tell, necessarily or otherwise?

A. I don't know.

X Q. 4110. Please refer to Defendant's Exhibit U, Carter patent No. 2,027,020, issued January 7, 1936. Commencing at line 50 of page 1 of this patent, Carter says, referring to Fig. 1:

"there is shown an antenna system adapted for unidirectional radiation of electromagnetic energy comprising an upper pair of conductors 1 and 2, which are made long relative to the length of the communication wave and disposed in a horizontal plane in V formation at an angle in such manner that radiation occurs principally along the bisector of the angle. This angle depends upon the length of the conductors and the wave lengths in a manner which is fully described in my United States Patent No. 1,974,387, mentioned above."

I think you have stated that that is consistent with the third Carter patent in suit, is that correct?

A. Yes, sir, but he goes on to explain something that is not explained in the third Carter patent in suit.

X Q. 1412. Namely, commencing at line 29, where he says:

"So far, the effects of ground upon resulting radiation have not been mentioned."

[fol. 438] Do you find that statement?

A. Yes, sir, I read that, if I recall, but I am not sure.

X Q. 1414. You will find the matter in your answer to Q. 398 (R. p. 320). It there appears that you read commencing with line 30, where it states:

"In both theory and practice it has been found that the reflections from the ground"

and so forth.

A. Yes, sir, so it appears; I did not recall. It did not make any difference.

X Q. 1415. Now, the subject of this Carter patent, Defendant's Exhibit U, was introduced to you by asking you whether you knew of any public statement made by the patentee, Carter, subsequent to the date of application of the

third Carter patent in suit, wherein he stated contrary to the statements contained in the patent in suit you have just referred to, and so forth—and I have been reading from Q. 398. Now, I ask you if you know of any earlier public statement made by the patentee, Carter, than that made in this patent, Defendant's Exhibit U, covering the same subject matter?

A. I believe there is something on this subject in the IRE article, which has been referred to already, I believe, earlier in the case,—Plaintiff's Exhibit 20.

X Q. 1418. The Carter, Hansell and Lindenblad article in the IRE proceedings in the fall of 1931?

A. Yes, sir, I do not remember in detail what it said there, but I believe the matter of the ground is taken up in that article.

X Q. 1419. And that is the article that is referred to, is it, in your answer to Q. 443 (R. p. 340), where you stated that you understood the article to deal rather in detail with [fol. 439] the subject matter of the patent in suit?

A. Yes, sir, that was the article to which I was referring.

X Q. 1421. Will you refer to page 1786 of the article, please, the middle diagram of Fig. 7? That shows, does it not, or purports to show, the power distribution in the vertical plane of an antenna placed above ground?

A. Yes, sir, that is right.

X Q. 1422. Then I refer you to page 1825, commencing at the third line of the page. The article states, "Fig. 47 is a contour map showing the power distribution on an imaginary sphere inclosing a complete antenna section. The antenna is considered as being in space far removed from ground. In the actual case the effect of ground must be considered."

Is that substantially what you stated this morning, the last sentence of that paragraph?

A. Generally speaking that is what I have been talking about.

X Q. 1424. You did state that the effect of ground must be considered in the actual case?

A. Well, it is true, and I may have stated it.

X Q. 1425. And is it correct that that statement refers to a figure, namely Fig. 47, which relates to a one bay model D projector?

A. It so states under the figure.

X Q. 1426. Do you or do you not know what a model D antenna is as described, generally described in this article?

A. I believe the model D is the one where the wires are at an angle to each other,—a V-type antenna.

X Q. 1428. And I refer you also to page 1828, Fig. 48, entitled, "Model D projector, power distribution in vertical plane." That shows, does it not, the effect of ground in a [fol. 440] similar way in which it is shown in the right hand figures of Defendant's Exhibits S and T?

A. Yes, sir.

X Q. 1429. Now, I read to you from page 1825 of Plaintiff's Exhibit 20. I want to read the next one or two sentences:

"The effect of ground on a horizontally polarized wave is such as to cancel radiation at zero angle to the horizon. Fig. 48 is a polar diagram showing the power distribution in a vertical plane when the antenna is located over perfectly conducting ground and over sandy ground such as at Rocky Point."

That is the figure we just referred to?

A. Yes, sir.

X Q. 1431. Now I want to take up the Abraham articles of 1898 and 1901. Is it not customary in engineering mathematics to use Greek letters to represent an angle?

A. Oh, yes, sir, you have quite a range of choice in symbols that you may use.

X Q. 1433. And symbols alpha, theta and phi are often used to represent angles, are they not?

A. Well, they were used by Abraham and they were used by Carter; and also theta sub zero in one case.

X Q. 1435. That is a difference you didn't point out between Abraham article and Carter, the theta sub zero?

A. Well, such difference would be a minor one.

X Q. 1436. Just about equally as important as the other differences?

A. Not necessarily, after all, there are quite a few letters in either the Greek alphabet or our own.

X Q. 1437. Or empirical symbols, so to speak, even?

A. Yes, sir, that is quite a range there.

[fol. 441] X Q. 1438. Both of these Abraham articles deal, do they not, with radiation from a single wire or a single conductor?

A. Yes, sir, that is true.

X Q. 1439. In answer to Q. 433 (R. p. 335), you referred to a single wire excited in its harmonics as a decidedly directional radiator. Am I correct in believing that you meant by that that it would have a radiation pattern as to its principal lobes, such as that of Fig. 1a of the third Carter patent in suit?

A. Or more accurately Fig. 1b.

X Q. 1440. Yes, I said as to its principal lobes.

A. Yes, sir, as to its principal lobes, that is all right.

X Q. 1441. And it also has additional lobes as indicated in Fig. 1b?

A. Yes, minor ones.

X Q. 1442. And those lobes, not only the minor lobes, but the principal lobes are conical, around the wire?

A. Yes, in other words, it does not matter, considering the wire as an axis, what angle you consider going around, in other words, it is cylindrical in nature.

X Q. 1443. Of course, that assumes also, doesn't it, that you are applying only one frequency to the wires?

A. Well, naturally, a frequency corresponding to the length of the wire in half wave lengths.

X Q. 1445. It assumes one frequency of that character is applied to the wire, does it?

A. Yes, one frequency.

X Q. 1446. Defendant's Exhibit W shows a difference, whether it is apparent or otherwise, between what you have labeled as the Carter angle, using the empirical formula, and what you have labeled the Abraham angle?

A. Yes, sir.

X Q. 1448. Over what range of wire lengths, in terms of wave lengths, does that difference appear?

[fol. 442] A. I believe I explained that in my direct testimony, that at a length of something in the neighborhood, of two wave lengths, the two curves merge as the length of the wire, in wave lengths, is made longer, and when it is made shorter there is a larger and larger discrepancy.

X Q. 1449. All of defendant's V antennas utilize wires which are more than two wave lengths long, do they not?

A. Yes, sir.

X Q. 1450. And above two wave lengths the two curves merge, as far as we can tell from this diagram, do they not?

A. Yes, sir.

X Q. 1451. Is there any formula given in either of the Abraham articles by which the angle of principal radiation can be determined without going through a rather complex mathematical computation?

A. The formula itself gives the angle of principal radiation and anybody at all familiar with the elements of mathematics should know how to find it. It does not have to be shown.

X Q. 1452. I am only questioning the use on here of the term "Abraham angle". I am not so sure that it is, in my opinion, proper, because, as I understand it, and correct me if I am wrong, the formula that Abraham gives is a formula which, if plotted for any particular length of wire, will show the radiation pattern of that wire?

A. That is correct.

X Q. 1453. And that the way in which you tell the angle of radiation of the principal lobe is by determining the maximum, or a maximum maximorum from that formula, is that correct?

A. That is correct.

X Q. 1454. That is, there are several maximum points corresponding to the corresponding lobes?

A. Yes.

[fol. 443] X Q. 1456. And to determine the proper angle for the main lobe, you have to determine the largest maximum?

A. Yes, sir, a very simple procedure. I mean, the presence of the formula itself tells the whole story, and inspection alone will tell you what the principal lobes are, or you might apply the elementary principle of differential calculus, where one determines the maxima by process of differentiation.

X Q. 1457. Will you please refer to Q. 440 (R. p. 339). As I understood the testimony at that point, you were suggesting that the Carter empirical formula was not correct, or was not necessarily correct, I don't know which, for points between wires of an integral number of half wave lengths long. Am I correct in that?

A. Yes, sir, you are correct in that.

X Q. 1458. Which? That it is not correct, or that it is not necessarily correct?

A. That it is not correct, because it is based on the Abraham formulæ which are correct only for an integral

number of half wave lengths, that is, you have discrete points.

X Q. 1459. Can you tell me or can you show me, for example, on Defendant's Exhibit W, by how much the formula determined according to Carter's angle would be incorrect at say the point between 6½ and seven wave lengths?

A. I cannot draw it on the curve from memory. Now, the difference is more apparent on the radiation resistance curve, one of which I produced, with a wavy line. What it all purports to show is that one can arbitrarily take assumptions or go beyond the original assumptions, and in this case, having been derived from the Abraham formulæ, [fol. 444] the Abraham formulæ being used, the Abraham formulæ applying specifically to an integral number of half wave lengths.

X Q. 1460. And therefore it would not be safe to assume that what you call the Abraham angle applied at all in the case of wires that were not an integral number of half wave lengths long?

A. No, it would not be safe to assume that, and that is what the angle alpha is based on.

X Q. 1462. Can you tell me by how much the angle departs from the correct angle at a point say between six and one-half and seven wave lengths?

A. No, I do not recall how much. At some point they are calculated and there is a difference.

X Q. 1463. And what is the order of the difference?

A. I don't remember that, it is not a large amount, I can tell you that.

X Q. 1464. Ten degrees?

A. I can not tell you how much.

X Q. 1465. Five degrees?

A. I can not tell you.

X Q. 1466. It might be as much as five degrees.

A. I don't recall, I will get you the information, and I think that will settle the whole thing.

X Q. 1467. I want to see what your recollection is. Might it be as much as five degrees?

A. I don't remember, sir.

X Q. 1469. It might or might not be one-tenth of a degree?

A. Well, that I don't remember also.

X Q. 1471. Defendant's Exhibits Y and Z represent, do they not, half of the radiation pattern from single wires?

A. That is correct.

X Q. 1474. That means one wire in each case?

A. That is correct.

X Q. 1475. As I understand Defendant's Exhibit Z, it is the radiation pattern for a seven and three-quarter wave lengths straight wire?

A. Yes, that is correct.

[fol. 445] X Q. 1476. And Defendant's Exhibit Y is for an eight wave length straight wire, is that right?

A. That is correct, sir.

X Q. 1477. Now, what is the difference in the magnitude of the main lobes in these two cases approximately, the order of difference?

A. Well, they are pretty near the same, one is slightly longer than the other.

X Q. 1478. About two per cent?

A. Very little.

X Q. 1479. And in the case of the seven and three-quarter wave length wire, the radiation at right angles to the wire is considerably greater, is it not, than in the case of the one-eighth wave length wire?

A. I should say not, looking at the diagram. Perhaps I have got the two turned around.

X Q. 1481. The radiation from the seven and three-quarter wave length wire would be considerably greater, in a direction perpendicular to the wire than in the case of the eight wave length wire, would it not?

A. Well, if you are picking a line—something that has no width, and picking it between these lobes, you may be right, but the radiation generally in the direction of right angles to the perpendicular of the wire is substantially less, in the case of Exhibit Z, which is for the seven and three-quarter wave length wire.

X Q. 1482. In the plane perpendicular to the wire, did you say?

A. No, in the direction perpendicular, that is as shown in these diagrams; I mean generally in the direction perpendicular, that is, a line drawn from the center towards 90, in that region.

X Q. 1484. These two patterns do not show the effect, of course, of a V antenna made up from wires of this length, do they?

[fol. 446] A. They show the possibilities of using such wires in various arrangements.

X Q. 1485. They do not show the radiation pattern of two such wires arranged in V formation?

A. Clearly not, because we have already stated that these are for single wires.

X Q. 1486. Have you compared the radiation patterns of an eight wave length V and of a seven and three-quarter wave length V with the angle specified in the Carter patent in each case?

A. There have been many radiation patterns prepared, and I do not recall offhand whether the ones you mention specifically have been or not; I will look and see. If so, you may have them.

X Q. 1487. May I ask what formula was used to compute the pattern of Defendant's Exhibit Z, the diagram of the seven and three-quarter wave length wire?

A. I did not compute these diagrams myself; I had them computed and I can supply you with the computation if you wish.

X Q. 1489. And you do not know what formula was used for that?

A. I do not remember.

X Q. 1490. Referring again to Defendant's Exhibits Y and Z, what is the difference in the angle of the principal lobes of radiation in those two cases, angle with respect to the wire?

A. They are very nearly the same.

X Q. 1491. And what is the difference in angle computed according to the Carter formula for seven and three-quarters as against eight wave length wires, approximately?

A. I should say about a degree.

X Q. 1492. And about how much would you say the difference was between Exhibits Y and Z?

A. Well, they look to me to be pretty nearly the same.

[fol. 447] X Q. 1493. How closely do you think you can judge that from these diagrams with your eye; you estimated the Carter curve with your eye, didn't you?

A. Yes, sir. I can't see any difference, it would be less than a degree, considerably less than a degree.

X Q. 1495. On that basis the Carter curve would depart for the seven and three-quarter wave length case by less than a degree from the correct angle, according to your exhibits, Defendant's Exhibits Y and Z, would it not?

A. Well, it would be determined in that manner, which, of course, is rough.

X Q. 1496. It gives an idea of the order of difference, does it not?

A. At that particular point on the curve.

X Q. 1497. Will you refer, please, to the Bethenod French patent No. 596,737. Do you find any statement in Bethenod as to the length of the wires of his networks?

A. I do, as to the electrical length of the wires of his networks. For example, in the translation, on the first page of the translation, the last paragraph beginning on that page: "A similar arrangement may be provided for the emission of short waves, and, in that case the antenna thus constituted may be operated at the harmonics." That means that it would be electrically long.

X Q. 1499. And that is the basis for your testimony, as I understand it, that the wires of his network are a plurality of half wave lengths long, is that it?

A. Yes, sir.

X Q. 1500. If we assume that is what that means, how short could the wires of his network be and still be excited harmonically, how short in terms of wave length?

A. One wave length.

[fol. 448] X Q. 1501. Now assume, referring to Fig. 1 of this patent, that the system that is harmonically excited is the system 2, 5, 6, 3, considered as a unit?

A. The patent does not so state, that it is considered that way. It says, "the networks." It does not specifically say the networks. On the other hand, he very carefully says that this should be excited at its harmonics, plural, and it is clear from that that he means not only the lowest harmonic but higher harmonics as well, the higher harmonics increasing the electrical length of the conductors.

X Q. 1503. Can you answer my question, making the assumption that I asked you to make, as to what that would indicate as to the length of the wires in the networks 2 and 3, if anything?

A. Well, the details of feeding and whatnot are not altogether clearly shown. He merely shows a wire connected to each pole of high frequency source and he has an optional arrangement for feeding them whereby he locates an oscillator on the pole, one of the poles between the horizontal portions, horizontal wires, also connected to opposite poles of a high frequency generator.

X Q. 1505. Now, supposing you were going to set up one of those systems and wanted to transmit signals from Sayville to San Francisco, and wanted to send them out at an angle of say ten degrees with the horizontal. How does he teach you to set up his system to arrive at such a result?

A. He does not go into such detail any more than the patents in suit.

X Q. 1506. Does he go into them any less than the patents in suit do?

A. At least he does not include errors which are very apparent in the patents in suit.

[fol. 449] X Q. 1507. Now will you read again, please, from the Bethenod patent what he does state as to directivity?

A. Yes, sir, I shall do that.

On page 3, the first paragraph, he states: "Obviously numerous other bearings are possible," that is, other than those shown in the figure where the wires are parallel in a horizontal direction, "particularly the two networks 2 and 3 in Fig. 1 may be arranged vertically"—that is two side by side vertically, still being parallel, "or even inclined, not only with respect to the ground but also with respect to one another so as to obtain directional effects either in a horizontal plane or in the vertical plane or in both planes." And then he adds again: "Furthermore, as is well known, the antenna may in all cases be, if necessary, excited in its harmonics.

X Q. 1508. That is all that he says about directivity, isn't it?

A. Well, isn't that all that he needs to say? We have a reference of a German article by Bontch-Broojevitch, where he goes into considerable detail in the matter of determining what radiation patterns and radiation resistance, and so forth, and the results of various combinations of wires excited at harmonics and arranged with half wave length radiator arrangements.

X Q. 1508. Can you tell me how you would set up the Bethenod system if you wanted to get directivity from Sayville, for example, to San Francisco, following the teachings of the patent?

A. Well, he says that you might incline these networks 2 and 3 with respect to one another, and to be excited in phase opposition, and one can vary the angle between them, [fol. 450] taking into account the ground, in such a way that the desired directional effect would be obtained.

X Q. 1509. And how would you do that following his teachings—what one of those arrangements would you use for example?

A. You would have a choice. I selected the one where the two networks 2 and 3 are inclined to each other.

X Q. 1510. There are, in fact, several ways of inclining them to each other?

A. Yes, quite a few ways. In other words, you do not exhaust all the possibilities by one or two examples.

X Q. 1511. In fact, they can be inclined to each other and still have all the wires parallel to each other?

A. No, I do not understand it that way. He says these two networks may be inclined to one another, and I take that to mean that they are parallel but inclined as to form an angle with each other.

X Q. 1512. If you have one network with the wires horizontal and with the network at an angle, and the other network with the wires horizontal and the network at an angle, are not the two networks at an angle to each other?

A. That is a possibility.

X Q. 1513. And in that case the wires are parallel, are they not, in each of the networks?

A. They could be parallel.

X Q. 1514. In the case that I have given they would be parallel?

A. They would be parallel if it is what I think you mean.

X Q. 1515. And that is another possible arrangement?

A. That is a possible arrangement. There are quite a few possibilities.

X Q. 1516. In fact, they are almost infinite?

A. Oh, no. You would have to not go beyond the region of what one skilled in the art would know what to do, and [fol. 451] the article by Bontch-Broojevitch that I just mentioned supplies plenty of information.

X Q. 1518. Isn't one of his teachings also that the network 3 is to be arranged below the network 2?

A. That is as shown in Fig. 1.

X Q. 1519. That is as shown in Fig. 1, and it is also mentioned in the specification, is it not?

A. Yes, sir, that is one of the arrangements.

X Q. 1520. And is it mentioned as one of the arrangements or is it the only specific arrangement mentioned?

A. Well, apparently he did not find it necessary to illustrate all the other arrangements. He happened to show

this one in Fig. 1, and then he speaks of the others as variations of Fig. 1.

X Q. 1521. If the network 3 were placed below the network 2 could you secure an antenna with its radiating wires in the same horizontal plane, be they either parallel or in V formation?

A. Well, as shown, naturally the wires, considering the two sides of the radiating circuit, are one above the other, but that doesn't prevent one from placing them in a horizontal plane; he openly invites one to do so.

X Q. 1522. But if one is above the other they couldn't be in the same horizontal plane?

A. No, that is what I said; I agreed to that.

X Q. 1523. Does Bethenod say anything about the wires of his networks being inclined with respect to each other as distinguished from the networks?

A. No, but the networks are composed of wires, and the wires of one network of course are fixed with relation to each other, they will be parallel.

[fol. 452] X Q. 1524. Does he indicate that there is any relation between the angle between the wires as they are inclined one to the other and the length of the wires or wave length, or anything of that nature?

A. No, he doesn't go into that; that is something that one can investigate.

X Q. 1525. And when you say that the arrangement of this patent, as I think you did say, is equivalent to the arrangement of the third Carter patent, you are applying to it, I assume, a knowledge that the wires should be at a correct angle, and that they should be at an angle with each other?

A. Well, if your idea of the third Carter patent is a definite specific angle, he doesn't go into that; he doesn't tell you that you must use a certain angle, but that is something for investigation; one can determine that experimentally, or to a certain extent, precalculate it.

X Q. 1526. And in the resume in the Bethenod patent it says nothing about directivity, does it?

A. No, that is simply added with the idea of pointing out one of the things that he had in mind, that is all.

X Q. 1527. Pointing out what he thought his invention was, is that correct?

A. Well, after having described the arrangement that I have been speaking of.

X Q. 1528. Mr. Kelley, we were discussing the Bethencd patent, 596,737, when we closed last night. I asked you to refer to Fig. 1 of this patent, and to consider that the system which is harmonically excited is the system 2, 5, 6, 3, considered as a unit, and then, with that assumption, I asked you what that would indicate as to the length of the wires in the networks 2 and 3, if anything?

[fol. 453] A. You understand, Mr. Blackmar, that the details of the feeding system are not shown.

X Q. 1530. Can you, under those circumstances, answer the question?

A. Well, without knowing the exact length of 5 and 6 and one must assume some reasonable arrangement of feeding, namely, that the feeding wires will be such that while the whole system will operate as you want it to, that is, with the harmonics, that it will produce the harmonics on the horizontal networks 2 and 3.

X Q. 1532. On that assumption, can you state whether anything is indicated with respect to the electrical length of the wires in the networks 2 and 3?

A. As to electrical length that would mean that the wires were electrically long, if they were excited in their harmonics.

X Q. 1535. If the system were excited in its harmonics.

A. Well, these wires are the radiators and they are the things that are excited in their harmonics.

X Q. 1536. Pardon me. I asked you to make a certain assumption, and I think that is disregarding the assumption.

A. I am afraid I don't understand your assumption, Mr. Blackmar.

X Q. 1537. Will you please refer to the other Bethenod French patent, No. 625,293; do you find any statement in this patent, Mr. Kelley, indicating that Bethenod considered the arrangement shown in the figure of the patent was that of a directional antenna?

A. Yes, sir.

X Q. 1538. Please refer to it.

A. On the second page of the translation, the paragraph beginning about the middle of the page:

"It should be noted that the invention may be subject to [fol. 454] many variations or modifications, as far as the

details are concerned: A plurality of antenna arrangements of the same type may be combined at the same station, and suitably oriented with respect to one another in order to obtain directional effects or to make possible multiplex operation."

X Q. 1539. Does that say anything about directivity from a single unit of his antenna as shown in the diagram?

A. No, but the diagram itself shows a directional antenna.

X Q. 1540. That is your interpretation of it, but does that state that the antenna as shown in the diagram of itself is directive?

A. Not in those words, no, sir.

X Q. 1541. Or in substance?

A. In the figure, as I said before.

X Q. 1542. I asked you about the specification?

A. Yes, and the passage which I just read is merely emphasizing the additional directional effects he can get by combination of a plurality of such radiators.

X Q. 1543. By using more than one of them?

A. Yes, but each one being directional also.

X Q. 1544. But the patent does not state that each one is directional also, does it?

A. No, sir.

X Q. 1545. In next to the last paragraph of your answer to Q. 464 (R. p. 354), it is reported that you stated that the patent taught the use of a radiating wire, a plurality of wave lengths long. I think you said somewheres else a plurality of half waves. Isn't the latter the correct statement?

A. Yes, and they, of course, would coincide if you come to two or four half wave lengths. I did not mean to make any such distinction, however. The patent said a plurality of half wave lengths.

[fol. 455] X Q. 1546. Is there anything in the Bethenod patent itself outside of your interpretation of the drawing that refers to the image of the antenna in the earth?

A. The specification does not go into that matter at all.

X Q. 1547. There is nothing in the patent to indicate that Bethenod knew that there was an image in the ground?

A. Oh, yes, sir, the figure in the patent shows the ground, and it was common knowledge with regard to the image produced in the ground, and it was, as I have stated several times, certainly from a theoretical standpoint, it was usually considered to be a perfect ground for determining as a first

approximation the general type of radiation that would be obtained from the system as a whole.

X Q. 1548. Now, please answer that question again as to whether there is anything in the patent to indicate that Bethenod knew there was an image of his antenna in the ground?

A. Yes. The representation in the figure, and the showing of the ground in the figure, in my opinion, was sufficient.

X Q. 1549. Sufficient to show that he knew there was an image, do you mean?

A. Yes, sir, that he was aware of the image that would be in the ground.

X Q. 1550. In other words, the mere fact that he shows the ground in the drawing, is that correct?

A. Yes, sir, coupled with the general knowledge of it. I am referring now to the Abraham article of 1901, where that idea is very clearly expressed, and that is the reason that I applied that knowledge in the case of Bethenod.

The Court: As I understand it, you say that it shows the ground, and from that you deduce that the man was pos-
[fol. 456] sessed of the knowledge of the time, and therefore considered that he knew it. That is what it means to me, anyhow.

The Witness: That is exactly the idea that I wish to express, your Honor.

X Q. 1553. Now, do you find anything in the Bethenod patent suggesting any reason for making his wire more than one-half wave length long, speaking of the radiation wire?

A. Yes.

X Q. 1554. Where?

A. He states at page 2, in the first sentence thereof:

"In order to obtain the greatest radiation efficiency for the antenna, the length of BC should preferably be equal to a whole number of half wave lengths."

X Q. 1555. And that includes one half wave length, does it not?

A. Yes, sir, a whole number.

X Q. 1556. That may be one or more?

A. One or more, yes, sir.

X Q. 1557. Now, would you please tell me, if you can, whether you find anything in there that suggests any desirability of having the wire more than one-half of one wave length long?

A. Well, I have to consider the fact that he uses plural when he speaks of the length of this wire, he says:

"The length of BC should preferably be equal to a whole number of half wave lengths."

I do not think that that rules out additional half wave lengths, in fact, I think it invites the use of additional half wave lengths.

The Court: Then the answer is "Yes".

The Witness: The answer is "Yes".

[fol. 457] X Q. 1558. I think that you also stated that that does include a wire one-half wave length long?

A. Yes, sir.

X Q. 1559. In other words, you cannot say "a whole number of half wave length"?

A. Not very well, sir.

X Q. 1560. Now, does Bethenod in this patent suggest there is any relation between the length of the radiating wire, the wave length that he uses and the magnitude of the angle D, which is the angle between the radiating wire and the horizontal plane?

A. He states, at the bottom of the first page of the translation, that is the last full sentence on the page:

"The portion BC of the antenna may form an angle D of any value from zero to 90 degrees with the horizontal."

He does not state specifically that some particular length is associated with some particular angle.

X Q. 1561. He does not suggest there is any desired relation between the wire length and the length of the wave and the magnitude of the angle; is that correct?

A. Yes, sir, that is correct.

X Q. 1562. Does Bethenod anywhere suggest in this patent that he has devised an antenna comprising two parrallel wires?

A. Yes, sir.

X Q. 1563. Where?

A. He says that the angle D may have any value from zero to 90 degrees.

When D has a value of zero, co-operating with its image, its image being parallel to it, then the system is one of two—the equivalent to two parallel wires, excited in phase opposition.

X Q. 1564. I did not ask about one that was equivalent, Mr. Kelley. Did he anywhere suggest that he has devised [fol. 458] an antenna comprising two parallel wires?

A. He shows it in the drawing.

X Q. 1565. The only two parallel wires in the drawing are the wires EF and AL, are they not?

A. I understood you referred to the radiators, not the impedance.

X Q. 1566. I did. All right, then, where does he show it in the drawing?

A. By showing the position of the ground in relation to the wire BC and stating in the specification that the angle D may be zero degrees.

X Q. 1567. That would give you, as you stated before, an equivalent, in your opinion, of a parallel wire antenna?

A. It is a very definite teaching.

X Q. 1568. A teaching by whom?

A. For example, Abraham.

X Q. 1569. But not by Bethenod? A. It is not expressly stated by Bethenod, but one must assume what is general knowledge.

X Q. 1570. And in order to find in this Bethenod patent, either a parallel wire antenna or a diverging wire antenna or a V antenna, it is necessary to consider the image in the ground, is it not?

A. Yes.

X Q. 1571. Now, will you please refer to your answer to Q. 464 (R. p. 353), where you stated, in connection with this patent, as follows:

"Nevertheless, in considering antennae in relation to the ground, it has been the custom of those skilled in the art first to assume that it is a perfect ground", and so forth.

I do not find, in that answer, that you have stated that they would assume secondly, or what would occur after [fol. 459] making the first assumption. Will you please explain that?

A. Well, I did not add that, because, as I explained in the course of my direct examination on this subject, I was considering what the Bethenod patent teaches one skilled in the art, and when one skilled in the art considers the radiating system with the wire above the ground, it has been the custom to consider the ground as a perfect reflector for electric waves.

Of course, after that, when one considers the actual installation, there are many other things to consider, but I was not considering such things, I was considering the teaching, and that is what is more than a suggestion as to the radiation that would be obtained if, instead of the wire co-operating with its image in perfect ground, the two wires were placed above the ground, and I think what I had in mind was very clearly brought out in the second Lindenblad patent, where Lindenblad starts out first with two wires excited in phase opposition above the ground, and then includes, as part of his disclosure, the use of one-half of that system above the ground, and the other half being omitted, since the half that is omitted will constitute then the image in the ground.

Of course, aside from that teaching, actually the ground encountered is imperfect and the exact equivalents of the radiation pattern will not hold. I am speaking only of the teaching involved, the fact that it is something more than a suggestion to go from one to the other.

X Q. 1571. Are you finished?

A. Yes, sir.

X Q. 1572. Then, as I understand it, in that answer you said first they would assume perfect ground?

A. Yes, sir.

[fol. 460] X Q. 1573. And discussed that, and if you had completed that thought, you would have said that then in the practical set-up it was necessary to consider conditions of actual ground, is that approximately correct?

A. That is correct.

X Q. 1575. Referring to your answer to Q. 473 (R. p. 358), you stated that with respect to defendant's antennas they were placed above the ground—I am not quoting you—they were placed above the ground at a distance of the order of a quarter of a wave length or thereabouts. Will you please refer to the tabulation, Plaintiff's Exhibit 13? The first sheet on the tabulation, the fourth line above the bottom,

indicates, as I understand it, the height of the antenna wires above ground in terms of wave length, is that correct?

A. Yes, sir, that is correct.

X Q. 1576. And those figures run from a minimum, I think, of .49 wave lengths with respect to antenna No. 8 to a maximum of, I think, 1.49 wave lengths in the case of antenna No. 6. Is that correct?

A. Yes, sir.

X Q. 1577. Are any of the defendant's antennas therefore a quarter of a wave length above the ground?

A. No, sir. In that answer I was speaking generally and from memory and did not attempt to be exact in saying a quarter of a wave length. The idea I had in mind was that it was sufficiently removed from the ground to come within the general range that Levy was speaking of.

X Q. 1578. As a matter of fact, they run from two quarter wave lengths to about six quarter wave lengths above the ground, do they not?

A. Yes, something of that order, but Levy's instructions were rather to keep away from the ground, and he men-[fol. 461] tioned a minimum of an eighth wave length.

X Q. 1579. Pardon me, that is not part of the answer to the question, I think. The question was as to defendant's antennas and their height above ground. Levy suggests, as I understand it, on this subject, referring, for example, to paragraph 4B of the resume of the original patent No. 593,570, height between one-eighth and five-eighths wave lengths, does he not?

A. Yes, sir, he does.

X Q. 1580. And a substantial number of the defendant's antennas are outside of that range, are they not?

A. Yes, sir, that is true.

X Q. 1581. Referring to the patent of addition, Levy patent of addition, Fig. 1 of that patent shows as its radiating members, so to speak, two networks, "1" and "2", doesn't it?

A. Yes, sir.

X Q. 1582. Paragraph 4J of the original Levy patent reads as follows: "The application of these arrangements for transmission and reception is envisaged particularly with short waves of less than a thousand meters wave length." Of course waves of 300 meters are less than 1,000 meters wave length, are they not?

A. Yes, sir.

X Q. 1586. And even 300 meters, for example, is a considerably longer wave length than the wave lengths utilized by defendant, is it not?

A. Yes, sir, but these dividing lines are rather arbitrary.

X Q. 1587. Surely; and in fact the dividing line, although it is not a true line, has been shifting over a period of years, hasn't it?

A. It changes quite a lot.

X Q. 1588. What do you find in the Levy patent of addition as to the length of the wires in the networks 1 and 2?

[fol. 462] A. The specification is silent as to the length of the wires of 1 and 2 in Fig. 1.

X Q. 1589. But the original patent, as I think you read, has a paragraph in the resume, namely, paragraph 4D, which indicates in that case a length approximating one-quarter of a wave length, doesn't it?

A. Yes, sir, referring to the figures shown not in the patent of addition, but in the first one I referred to.

X Q. 1590. Now I will ask you to assume that in Fig. 1 of the patent of addition the networks 1 and 2 are composed of wires of approximately a quarter wave length in length. With what position of those wires would you secure the best directivity?

A. Something, I should say, a little greater than 90 degrees.

X Q. 1591. And in what direction with respect to the bisector of the 90-degree angle would that directive radiation take place?

A. It would be in the vertical plane of the bisector.

X Q. 1593. And as far as the horizontal directivity pattern is concerned, what would be the best angle for the two networks?

A. Well, I wouldn't be able to state that offhand. I am sure, however, that I can obtain for you the necessary information. It isn't the sort of thing that can be answered offhand.

X Q. 1594. And if the wires were placed 180 degrees apart, for example, that would approximate what we have been referring to as a di-pole in this case, would it not?

A. Yes, sir, that would approximate a di-pole.

X Q. 1595. Now will you please refer to the Brown British patent No. 14,449. Referring to page 2 of this patent I note that in reading the patent you skipped the two-line para-

[fol. 463] graph commencing at line 12. Will you please read that?

A. "The said wires may be closed at the top or not, and they may or may not be provided with an earth connection."

X Q. 1596. If they were closed at the top, would they be open-ended wires?

A. No, sir, then they would be short-circuited.

X Q. 1597. Do you know what the directive pattern in the horizontal plane of such an arrangement as that of Fig. 1 would be?

A. It would approximate two tangent circles.

X Q. 1598. In other words, approximately the directive pattern that appears in Fig. 1 of the first Lindenblad patent in suit, I think it is?

A. Yes, sir, something like that.

X Q. 1599. And in free space, if this antenna were placed in free space, what would be the principal direction of radiation with respect to the wires themselves?

A. It would be in the plane of the wires, but at right angles (90 degrees) to the wires.

X Q. 1601. Now, refer to Q. 487 (R. p. 364); am I correct in understanding that your answer to that question was intended to apply to the defendant's antennas, in view of the preceding question?

A. I was not referring to the wires of defendant's antennae, no sir.

X Q. 1603. What were you referring to?

A. I was answering a general question without reference to anything in particular except the question itself. The question reads: "Now, what would have to be the necessary relation of the wires of the antennae" in order that radiant action would occur in a direction making the same angle with each conductor?" That is a perfectly general question, [fol. 464] and my answer is: "The wires in that case would have to be parallel."

X Q. 1605. Is it not correct that the defendant uses an arrangement of wires in which the wires are not parallel, yet the predominant radiant action occurs in the direction named, the same angle with respect to each of the two wires of the V?

A. Defendant's antenna wires do not radiate forming the same angle with each of the wires, no, sir.

X Q. 1607. How much difference is there between the angles?

A. The one is a positive angle and the other is a negative angle. The magnitudes are the same but the signs are different.

X Q. 1608. Numerically they are the same but the signs are different?

A. Yes, sir, and that makes the angles different.

X Q. 1609. In other words, take, for example, defendant's antenna No. 8, in which, as I understand it, the wires are at an angle of 45 degrees with respect to each other. Let us first consider the bisector as being in an easterly-westerly direction for convenience of reference, so that one wire is 22½ degrees on the south side of that bisector and the other wire is 22½ degrees on the north side of that bisector. Now, the predominant radiant action takes place from the southerly wire, for example, at what angle to the wire?

A. At 22½ degrees in a conical lobe.

X Q. 1612. And in the case of the other wire what is the direction of the predominant radiation?

A. 22½ degrees in the conical lobe. May I add that the conical lobe, of course, extends all the way around the wire, and that it is not the same direction from the axis in which the reinforcement takes place.

[fol. 465] X Q. 1613. All right, I probably did not go far enough; I should consider the two wires when they are both working together, because that modifies the radiant action, does it not?

A. Yes, you get the combined effect then.

X Q. 1614. And now let us consider the antenna as a V antenna. Possibly, instead of No. 8, we had better take a single V for simplification. But we will assume the same angle, so as to go on without changing our figures. With the antenna set up as a V, what is the direction of predominant radiation from, for example, the southerly wire?

A. 22½ degrees on the north side.

X Q. 1618. And what is the direction of predominant radiation from the other wire with respect to the wire where they are combined?

A. 22½ degrees on the south side of the north wire.

X Q. 1620. Now, will you please refer to the Japanese patent, or to the translation of it, rather. Do you understand from the specification that Fig. 2, that is the upper left-hand figure on the sheet which contains six figures, is a diagram of an experimental arrangement?

A. Yes, sir, I so understand.

X Q. 1622. And does this state what the wave length was in that experimental arrangement?

A. I believe it was stated to be 40 meters.

X Q. 1623. And what is the length, the electrical length of the left-hand wire, the left-hand vertical wire of the two parallel wires in the figure?

A. The left-hand wire would be slightly greater than a half-wave length.

X Q. 1625. And how about the right-hand vertical wire?

A. That is given all values from the same length as the [fol. 466] left-hand wire to the values marked on the figure: 26 meters; 16 meters; 11.86 meters; 8.7 meters.

X Q. 1627. So that in no case is the right-hand wire indicated to be longer than the left-hand wire, is that correct?

A. Not in this figure.

X Q. 1628. Do you consider the vertical wires shown in Fig. 2 to be electrically long wires?

A. Well, I would say that they are electrically long, a half-wave length long is of pretty good electrical length.

X Q. 1629. So that any wire that is at least a half wave length long is, in your definition, electrically long?

A. Well, I would not make a hard and fast rule of it. After all, it is a shifting thing, depending on how you happen to feel about it. That is, it is not something where you can draw an arbitrary line any more than for instance in connection with what is long wave and what is short wave.

X Q. 1630. Now, in this system of this Japanese patent, he staggers his wires at an angle, I think, theta?

A. It is so marked on Fig. 2 and Fig. 1 also.

X Q. 1632. Now, so far as Takagishi describes the action of this antenna, does he sugegst that there is any relation between the angle of stagger and the angle of predominant radiation from one of his wires?

A. No, sir, that is not what he is trying to show in this patent.

X Q. 1633. In answer to Q. 492 (R. p. 366), you stated:

"he offsets them" (that is, the wires) "at an angle with respect to one another in order to obtain his control of direction that I mentioned."

[fol. 467] With the arrangement shown, does he obtain that control?

A. I should say that he would have some control, although I believe it is not particularly good in that respect, but this

is something additional to merely using two electrically long wires in parallel. As he states, he wants to obtain something additional.

X Q. 1634. Now, will you please refer to page 3 of the translation, the page that contains a table near the bottom. Now, with respect, first to the columns of that table, the number of the harmonic represents what, according to your understanding?

A. The number of the harmonic there represents, according to my understanding, a number of quarter wave lengths.

X Q. 1637. And what does the angle against the horizontal plane represent to you?

A. The angle at which the principal lobes of radiation would be sent out with reference to the horizontal plane.

X Q. 1639. In other words, the complement of the angle between the lobe and the wire, is that what you mean?

A. That is correct.

X Q. 1640. On that basis, is the table correct?

A. No, sir, the table is not correct. It so happens that I have not marked in my copy where it is incorrect, but, as I recall, there is one value given which is incorrect.

X Q. 1641. And that table relates, does it not, to radiation from a single vertical wire?

A. Yes, sir, the type of wires, as I understand it, that Takagishi intended to use.

X Q. 1642. But so far as his disclosure is concerned, he makes no utilization of that angle of principal radiation, does he?

A. Well, he doesn't go into it in detail, but he must make [fol. 468] use of it, since he is using the electrically long wires, and he knows of it, because he gives it in the table.

X Q. 1643. Yes, but it does not appear that he considers that that enters into the vertical directivity, that he is securing by the arrangement shown, does it?

A. Yes, sir, I think it does.

X Q. 1644. In the arrangement of Fig. 2, for example, the experimental set-up, he would not be utilizing that, would he?

A. In that particular figure, the wires would not be long enough to give him the inclined lobes, being only a half wave long.

X Q. 1645. Nevertheless, he was intending to secure inclined radiation with that arrangement, wasn't he, as appears from the specification?

A. He was endeavoring to secure control of the angle, and this, as I understand it, was an experiment that he carried out.

X Q. 1646. Yes, an experiment upon which he bases, as I understand, the arrangement he suggests using in the figure, to control the angle of radiation, is that correct?

A. Yes, sir, I think you are correct.

X Q. 1647. You read from page 2 of the translation a statement of the patentee that this invention makes possible efficient communication by adjusting the radiation angle, depending upon the distance between the transmitting and receiving stations. Do you agree that this invention made that possible?

A. Since I haven't tried it, I could not answer your question satisfactorily.

X Q. 1648. As a matter of fact, you stated you were not sure it would work the way he said, didn't you?

A. I am not sure that it would be a very good arrangement. I can see difficulties in it, but I do not mean to say it could not possibly work.

[fol. 469] X Q. 1649. Now, in Q. 495 (R. p. 366), referring to this patent, you were asked:

"Is it or is it not the angle of offset"—(that is theta that is being referred to)—"between the wires in exactly the same sense as the angle alpha is employed in Fig. 4 of the first Lindenblad patent?"

Your answer was:

"It is the angle of offset of the ends of the wires."

But am I not correct in stating that it is not the angle alpha in the sense of Lindenblad with respect to the direction of predominant radiation from the wire?

A. Do I understand that you are doubting the correctness of my answer?

X Q. 1650. No, I am doubting whether you answered the question as asked, that is all. Your answer, I think, is correct.

A. Oh, no, it does not correspond to the angle alpha in the first Lindenblad patent. It is merely the angle of offset of the wires.

X Q. 1651. Will you please refer to the Heising patent, 1,562,961. You referred to Fig. 10 of this patent, and re-

ferred to the lines marked 20 and 21 of this diagram as wires. Do you understand that they are intended to represent plain linear wires?

A. Taken in conjunction with the rest of the figures, I understand that they refer to a transmission line which is loaded; in other words, loaded at sufficiently close intervals, electrically speaking, that it is equivalent to its new line.

X Q. 1652. In other words, line 20, for example, might represent the antenna 2 of Fig. 2 or Fig. 1, or the antenna [fol. 470] of Fig. 4?

A. Yes, sir, that is my understanding.

X Q. 1654. Heising does not suggest, does he, that those wires are plain wires?

A. He doesn't say that they are plain wires, and when I used the term "wires" here, I was thinking of transmission line, which all these figures show where they show the antenna.

X Q. 1655. The type of wire of the antenna that the defendant uses is not of the type of wire there?

A. No, it is not a loaded wire.

X Q. 1656. Will you please refer to Fig. 8? Have you any understanding as to the length of the antenna in that case, in wave length?

A. Yes, sir, 12 wave lengths.

X Q. 1657. Do you know what the frequency involved is?

A. On the same page, page 4, there is a frequency of 50,000 cycles mentioned.

X Q. 1658. How long would you say a 12 wave length wire would be at a wave length corresponding to 50,000 cycles, approximately?

A. It would be 48,000 meters long.

X Q. 1660. Somewhere in the neighborhood of 30 miles, generally speaking?

A. It would be something under 30 miles, but in that general range.

X Q. 1661. Does the angle theta in Fig. 8 correspond to the angle of principal radiation of a plain wire 12 wave lengths long?

A. No, sir, it refers to the angle of principal radiation of a loaded wire 12 wave lengths long.

X Q. 1662. And that follows a different law, does it, as to angle of radiation, from a plain open-ended wire?

A. It is very closely connected with it.

XQ. 1663. How close is this angle theta in the case of Fig. 8?

A. The size of the angle would be different, but you spoke [fol. 471] of the law it followed, not specifically the angle, but there would be quite a difference in the angle. In other words, the Abraham angle, that is to say, the angle of the principal lobe of radiation which one would derive from the Abraham formula on the unloaded antenna 12 wave lengths long, would be inclined to the wire at a much smaller angle than this angle theta, shown in Fig. 8.

XQ. 1664. Does Heising illustrate here standing wave or traveling wave antennas?

A. These are traveling wave antennas.

XQ. 1665. With a traveling wave antenna as described by Heising what controls the angle of radiation from the wire?

A. There are several things that control the angle of radiation from the wire. There is the electrical length of the wire, and also the phase shift along the wire, apparent velocity of the waves on the wire compared with their velocity in free space.

XQ. 1666. Will you please refer to page 3 of this patent, line 102, "When the ratio,"—do you know what ratio he is referring to there?

A. I think I do; the ratio of the velocity in the wire to the velocity in free space, that I have just mentioned.

XQ. 1668. "When the ratio is infinite," that means, does it not, when the apparent velocity of the wave along the wire is infinite?

A. That is right, when there is no phase shift along the wire at all.

XQ. 1669. "When the ratio is infinite the wave front will obviously be parallel to the conductor and the direction of propagation will be perpendicular to the antenna. When this ratio is less than unity, the antenna is not directive."

[fol. 472] Do you agree with that?

A. No, sir, I do not.

XQ. 1670. According to the teaching of what I read to you, however, that means, does it not, that when the apparent velocity of the wave on the wire is anything less than the velocity of light, the antenna is not directive?

A. That is what he says.

XQ. 1672. What is the apparent velocity in the case of defendant's antennas with respect to the velocity in free space, do you know?

A. Well, I have to make certain assumptions. It is very nearly, I should say it would be somewhat less but very close to the velocity of light.

X Q. 1673. That is my understanding of it, but the ratio of that velocity to the velocity in space would be less than unity?

A. Yes, because you have resistance in the wire and that always slows up the wave.

X Q. 1674. And under those circumstances, as stated by Heising, the antenna would not be directive, lines 105 to 107 on page 3?

A. He so states, but he uses a different ratio.

X Q. 1675. What do you mean by a different ratio; he had his antennas using a different ratio, is that what you mean?

A. Yes, taking Fig. 8, for example, that would be something intermediate.

X Q. 1676. I understand that, but your answer might be misunderstood, I think. The ratio that he is referring to in line 106 is the ratio that we were talking about, namely, that of the apparent velocity of the wave to its velocity in free space, is it not?

A. Yes, sir, and also not to have the answer misunderstood, he loads the antenna wire and actually does attempt to increase the velocity. That is the way he uses it.

[fol. 473] X Q. 1677. And that is the way he thinks he can secure directivity?

A. Well, he can secure directivity that way.

X Q. 1679. Comparing the arrangement of Fig. 10 of this patent to Fig. 4 of the first Lindenblad patent, am I correct in understanding that in the case of Heising the cancellation takes place in the direction from the shorter to the longer wire, that is, in the direction 23-22?

A. Well, it isn't a case of a shorter or longer wire, you mean the one that is placed to the left?

X Q. 1680. I was looking at the diagram when I was saying that; cancellation takes place in the direction of lobes 23-22, is that correct?

A. Yes, sir, that is correct, because the wires are cophasially fed.

X Q. 1681. And in the case of Lindenblad, Fig. 4, the cancellation takes place in the opposite direction with respect to the stagger of wires, is that correct?

A. Assuming that they are correctly spaced, and by virtue of the same principle.

X Q. 1713. Do you know where it would be, the principal or predominant radiation?

A. It could be determined. The two diagrams are not resolved into one, and that would have to be done in order to answer your question.

X Q. 1714. In each of these cases, as I understand it, the angle between the wires was chosen, wasn't it, to specifically indicate minimum radiation along the bisector of the angle?

A. Yes, sir, in accordance with Mr. Hogan's interpretation of the second Lindenblad patent.

X Q. 1715. You don't mean he suggested that he chose an angle to show minimum radiation along the bisector?

A. Well, I believe the statement was made that if these instructions were followed as to the angle, that predominant radiation would be along the axis of the antenna system, and no exception was made as to any angle or any hint that perhaps there would be an angle where there would be no radiation, or very little.

X Q. 1716. Again, may I ask: Were these angles chosen specifically to show minimum radiation along the bisector of the angle?

A. I had them worked out for me, and my understanding is that they were so chosen.

X Q. 1722. We also discussed the radiation diagrams of V's utilizing wires of eight wave lengths and seven and [fol. 477] three-quarters wave lengths. I asked you whether you had determined what the radiation diagrams of V antennas with the correct angle, according to Carter, would be for wires of eight and of seven and three-quarters wave lengths long, and you said, as I recollect it, that you did not know whether those diagrams had been prepared but you would find out. Could you find out whether they have been plotted?

A. Yes, I will be very glad to do that.

X Q. 1726. And furnish copies of them to me?

A. Yes, sir, I will do that.

Mr. Darby: Wait a minute, Mr. Blackmar, I will try to find that for you in a moment.

Mr. Blackmar: I want to know whether you plotted out radiation diagrams of a V antenna made with wires of these wave lengths, and with the angle as specified in Carter.

Mr. Darby: I do not think they have. These were plotted under my general supervision and direction to show specific

things, and I do not recall having instructed any plotting of that kind to be made.

X Q. 1727. One other thing I asked you to do is to determine the difference with respect to the third Carter patent, Fig. 12, between the curve shown there and what you consider to be the correct angle for a wire of a wave length between an integral number of half wave lengths, such as 6¾ or 7¾?

A. I feel pretty sure you did not ask me to give you that information, although we discussed that, and I told you I couldn't answer it offhand, and then we discussed afterwards, other exhibits showing radiation, the diagrams in the [fol. 478] two exhibits you have just referred to, for instance, given seven and three-quarter single wire and eight wave lengths single wire, and I said it was a matter of a degree, and I thought that was all you wanted to know.

X Q. 1728. Originally you stated it might be as much as five degrees?

A. No, sir, I said I couldn't remember, I gave you no values at all. The fact was, I couldn't remember.

X Q. 1730. Mr. Kelley, just one more subject in connection with the second Bethenod patent, No. 625,293, which is the one showing a slanting wire radiator. Assume this time the presence of an image; what is the direction of principal radiation from this antenna?

A. And also assuming a perfect ground, it will be in the horizontal direction, in other words, along the angle of the bisector between the wire and its image, that is, the wire BC and its image.

X Q. 1732. Supposing it is set up over actual ground, not perfect ground, as I understood you to say yesterday that perfect ground does not exist, is that correct?

A. That is correct, perfect ground does not exist. If that is set up over imperfect ground, the maximum radiation will be inclined to the horizontal.

X Q. 1733. In view of that statement, going back to Plaintiff's Exhibit 36 for Identification, would you be willing to sketch in, in the upper figure 4, on the sheet, and Fig. 5, the general nature of radiation in the principal direction?

A. Yes. I understand this is not for the purpose of drawing any quantitative conclusions?

X Q. 1734. That is correct.

A. And, if you will remember, yesterday I hesitated be- [fol. 479] cause I wanted to be absolutely sure about imper-

X Q. 1682. You mean "Yes, assuming they are?"

A. "Yes, assuming that they are."

X Q. 1683. Now will you please refer to the article in Q. S. T., the Melton article? What do you find in this article with respect to directivity?

A. The subject is not explicitly discussed in the article at all.

X Q. 1684. Does he anywhere show, disregarding the so-called image, the use of, or does he suggest the use of parallel wires as an antenna?

A. Assuming that I must disregard the image, he does not.

X Q. 1686. Or staggered wires or V wires?

A. The same answer applies.

[fol. 474] X Q. 1687. Now, you have referred to the book of Mills on Radio Communication, and particularly a formula or formulæ that appear on page 156. Could you determine from this formula the directive effect of the combination of two electrically long wires?

A. This formula would be a very necessary adjunct; one would have to do more than that, one would have to use Abraham, Bontch-Broojevitch, and what other information was available.

X Q. 1688. And that would be true whether you were referring to parallel long wires, or long wires in V formation, would it not?

A. Yes, sir, if you are now speaking of the matter of radiation patterns in all directions; nevertheless this is the nucleus of it. In other words, spacing and phasing are fundamental things to know as well as relative amplitude in any particular direction, and knowing those three things one can determine what the radiation is in that direction as compared with some other direction in which the same elements are also known.

X Q. 1697. Now will you please turn to Q. 523 (R. p. 376). In an answer relating to directivity of antenna systems you said "the first Lindenblad patent certainly if arranged as it was intended to be arranged so as to obtain the intended object,"—by that I presume is meant assuming the correct stagger and correct spacing?

A. Yes, assuming the corrections in the disclosure.

X Q. 1698. (Continuing reading)—"would be fully as directive as the third Carter patent," and of course you meant there the structure made under the third Carter patent?

A. Yes.

X Q. 1699. Do you agree that as compared, for example, to the standard di-pole as a standard, the power gain, as we [fol. 475] defined it yesterday, in the desired direction, would be greater with the V arrangement of wires than with the parallel arrangement of wires?

A. My recollection is there certainly would be very little difference; that is, it would depend largely on this definition.

X Q. 1700. Which definition?

A. That you advanced in regard to directivity.

X Q. 1701. Have you the definition in mind?

A. I think I know what you mean, and I would say that there would be very little difference, if any.

X Q. 1704. What does this diagram of Defendant's Exhibit G show with respect to the radiation of the two wires, combined radiation of the two wires in the direction which someone has marked "Axis of the Antenna"?

A. It shows four units in that direction.

X Q. 1705. In the direction vertical to that?

A. Four hundred.

X Q. 1707. In connection with Defendant's Exhibit BB you stated that that represented wave patterns illustrating exactly the same results as those of Exhibit G; you said, in answer to Q. 542 (R. p. 378): "In so far as direction of predominant radiation is concerned with an angle less than 45 degrees." What did you mean by exactly the same results as represented by Defendant's Exhibit G, "in so far as the direction of predominant radiation is concerned"?

A. I assumed by "exactly the same results" in my answer that the same principle was shown, namely, that predominant radiation would be elsewhere than predominantly along the axis of the conductor system.

X Q. 1710. What is the direction of predominant radiation in a system such as that shown in Defendant's Exhibit [fol. 476] BB?

A. It will be in a multiplicity of directions. You could hardly say then that it was predominantly in any direction, but it certainly is not predominantly along the axis.

X Q. 1711. Yes, but the actual predominant radiation, can you state in what direction that would be with respect to the bisector of the angle?

A. The largest part of the radiation will not be along the bisector of the angle.

fect ground, and I assured myself on that point, and I will give you now in a very general way what the general appearance would be.

X Q. 1735. When you say you were not sure as to imperfect ground, you meant you were not sure as to its effect?

A. No, sir, it was not that, it was as to quantitative values.

X Q. 1736. I am not asking for quantitative values in this case, only qualitative.

A. Yes. In the part of the sketch marked upper Fig. 4, I will extend the line for ground. And while I have not room on here, I am assuming that ground is not limited by the ends of the line showing ground. I mean to show the lobes in either direction to be the same or approximately the same. I think I have completed it, so far as you have asked me.

Mr. Blackmar: Now, this sketch states that the wire is four wave lengths long. I just want it understood that I am not by that indicating that I consider the wire in the Bethenod French patent as of any such length.

I offer the sketch that has been drawn by the witness on this Plaintiff's Exhibit 36 for Identification.

The Court: Very well.

X Q. 1746. Now, as I understood you, you have said, for example, in answer to X Q. 1404 (R. p. 436), that the differences of angle where they occur and the upward tilt of the beam of propagation due to the presence of the ground, are the only functional differences between defendant's antennas and antennas constructed as taught by the third Carter patent. Now, isn't it a fact, that aside from the dif- [fol. 480] ferences of angle between the sides of the V's found in some of the defendant's V antennas at Sayville, whose antennas are constructed as taught by the third Carter patent?

A. Assuming the functional differences?

X Q. 1747. Aside from the differences of angle where they exist?

A. Well, I do not so understand, and as you appreciate, I had nothing to do with the design of these antennas.

X Q. 1748. But I am speaking about their construction as it exists today, and not as to whether they were intended to be constructed in one way or another, but as they exist today.

A. As they exist today, I should say they are not constructed in accordance with the teachings of the third Carter patent.

X Q. 1749. Even aside from the question of angle between the wires?

A. Well, I do not see how I can leave that out of consideration because that is part of the teaching, or not

X Q. 1750. My question said, "Aside from that difference?"

A. Well, if you mean by your question, whether the antennas are generally V-shaped, in very general terms, yes, sir.

X Q. 1751. So far as the upward tilt of the beam is concerned that, I understand you have testified, is inescapable in an antenna constructed above the ground, is that correct?

A. It is true of any antenna.

X Q. 1753. And it is escapable, is it, in any antenna constructed above the ground, is that what you mean?

A. Well, it is inescapable, that is what the ground does to it.

X Q. 1754. Using wires, say, seven or eight wave lengths long, if you wish to retain the advantages of sharpness of [fol. 481] directivity made available by using proper angle between the wires and wish to get your beam tilted upward more than inevitably results from placing the horizontal V antenna over the ground, and wish to get, say, 20 or 25 degrees angle of tilt, as a matter of fact, is it not true that you could do so by tilting the plane of the V upwards as taught in the Carter patent?

A. The result would not be as good, and it would not be as good as one would not be making effective use of the ground, and it is just that point in connection with the third Carter patent, where the teaching is at fault.

X Q. 1755. If you wanted to get a beam of approximately 20 or 25 degrees from the ground, could you not do that by tilting the plane of the antenna as taught by the Carter patent?

A. I dare say you could.

X Q. 1756. Does any of the references to which you have referred herein show at a date prior to that of the application for the third Carter patent in suit any practical directive antenna system, comprising two or more wires, each of several wave lengths in length, which in its principle of operation makes any use of the relations which are expressed in, or may be derived from the Abraham formulas to which you have referred?

A. Yes, sir.

X Q. 1757. Which one?

A. The first Lindenblad patent, assuming correct instructions, does so.

X Q. 1758. Is there any other?

A. The second Lindenblad patent, assuming Mr. Hogan's interpretation of it, as a standing wave antenna, forming a V with the theoretical radiation along the bisector of the angle, along the axis of the conductor system, assuming all this, the second Lindenblad patent also.

[fol. 482] X Q. 1759. That is assuming that the correct angle is applied to it, is that what you mean?

A. Yes, sir.

X Q. 1760. Is there any other reference that meets the question that I have asked?

A. Takagishi using the two electrically long linear conductors, excited in phase opposition, if proper spacing with that phasing were used, would also be a reference of the type that you have asked for.

X Q. 1761. Any other?

A The French patent to Bethenod, No. 596,737, assuming again the proper spacing and phasing relations between the radiators.

X Q. 1764. Is there any suggestion in that patent as to use of the relations expressed in the Abraham formulas?

A. No, sir, I assume that was well known.

X Q. 1765. Have you completed the main question as to references that meet those specifications?

A. I think so, but if I may have a few more moments, I would like to make it complete. The British patent No. 14,449 to S. G. Brown.

X Q. 1767. You remember that one of the statements in the question was wires each of several wave lengths in length.

A. I am sorry. Well, then, although in my opinion, this is an anticipation, nevertheless, with that limitation, I can not very well include it.

X Q. 1768. Is there any other that you still wish to check?

A. That is all that I can think of at the moment.

Mr. Blackmar: That is all.

Redirect examination.

By Mr. Darby:

R. D. Q. 1769. You indicated, Mr. Kelley, that there was some comment you would like to make in connection with

[fol. 483] Plaintiff's Exhibit 36 for identification. Will you please make that comment now?

A. Yes, sir. I noticed when this was submitted to me that I was asked to draw the principal lobes of radiation in a general way for two classes of radiators, if I may put it that way, one where the wire and its image cooperate. the wire being inclined to the surface of the earth and its image likewise by nature also inclined; and the other class with two wires inclined to each other. I was asked to put these lobes in looking edge on to the V wire, that is, where the two wires are present, namely, in the direction where one wire covers the other wire as you look at it. In the other case where there is the inclined wire above the surface of the earth I was asked to put the lobes in looking at it from a plane perpendicular to that.

Referring to the upper Fig. 4, which is for the inclined wire with a perfect ground, had I been asked to draw the principal lobes looking down on the wire, in other words, making it comparable with the showing for the two wires which is given in the lower Fig. 2, then the diagrams would have been identical.

R. D. Q. 1770. Now, you were asked about tilting those wires of the third Carter patent in suit at an angle to the horizontal surface of the earth in connection with obtaining a desired angle of say around 25 degrees to the horizontal. My question is does the Carter patent teach expressly or impliedly anything about obtaining principal radiation at any angle to the plane of the wires?

A. No, nowhere in the third Carter patent is it taught to do anything but radiate in the plane of the wires.

[fol. 484] R. D. Q. 1771. Likewise you were asked about the two angles which the additive lobes of radiation make to the wire from which the lobes emanate in a V type of antenna, and in the example given, namely, 45 degrees, you stated, if I recall your testimony correctly, that one angle, that is, the angle made by one lobe, would be minus 22½ degrees, and the additive angle made by the other lobe would be a plus 22½ degrees in the example given. Was or was not your answer given in considering that type of antenna in free space?

A. It was given assuming the antenna to be in free space.

R. D. Q. 1772. I think you likewise referred in your cross-examination to the I. R. E. article by Carter, Hansell and Lindenblad, Plaintiff's Exhibit 20, with reference to dis-

closures therein of ground effect as a prior statement of Carter, that is, prior to the date of the Carter patent which has been marked in evidence as Defendant's Exhibit U. Will you please state what justification you have for referring to the statement in this article as a prior statement of Carter's?

A. I was speaking generally, and I had no justification for attributing that statement to Mr. Carter in view of the joint authorship of the paper.

R. D. Q. 1773. Likewise, with reference to your testimony on cross-examination concerning the differences between the functions and principles of operation of the third Carter patent in suit, No. 1,974,387, you testified that the ground effect and angle between the legs of the V, as I recall it, were the only differences between the functions and principles of operation of the antenna disclosed in the third Carter patent in suit and defendant's antennas. In giving [fol. 485] that answer did you have in mind the statement in the Carter patent on page 4, line 35, the paragraph beginning at that point?

A. Yes, sir, I did.

R. D. Q. 1774. If for any reason you considered the Carter patent to be confined in its disclosure to the use of a multiple of half wave lengths, would your answer have been the same?

A. No, sir, I would have added that there was also a difference as to the electrical length of the sides of the Vs, with the single exception of antenna No. 8, which is four wave lengths long.

R. D. Q. 1784. It was brought out on your cross-examination that in the comparitive charts which are in evidence as Defendant's Exhibits S and T, you assumed perfect ground. Have you had charted, for similar comparative purposes, the same effects at an angle of 45 degrees, at an angle of 50 degrees, as applied to antenna No. 8, with the worst possible ground?

A. I have had such diagrams calculated, and the character of the ground is much poorer than one would encounter in practice, and it shows the same relative effect. Namely, with the angle of 45 degrees the radiation resulting from the cooperation of the antenna and its image in the ground is greater, in the maximum direction, than had the angle 50 degrees been used, the angle 50 degrees being the angle

calculated from the Abraham formula and specified by Carter.

R. D. Q. 1786. What would you have to say as to actual condition of the ground in so far as its comparative effect is concerned, in the various instances?

A. In these two exhibits I think that point is clearly brought out, since we go all the way from perfect ground [fol. 486] to something which is poorer than anything one would be likely to encounter, and the same general effect is maintained.

Mr. Darby: I offer one of the charts in evidence showing the worst possible ground.

(Marked Defendant's Exhibit HH in evidence.)

R. D. Q. 1787. I see that you have made this chart or had it made only with respect to antenna No. 8.

A. Yes, sir.

R. D. Q. 1788. Would there be any difference in the comparative effects if it were worked out in connection with all the other antennæ of the defendant in actual use by defendant, and I am excluding antenna No. 2 as rebuilt?

A. Has the same general effect. By that I am assuming the effect of going from perfect ground to extremely poor ground, that whatever would hold for the perfect ground will also in general hold for the imperfect ground, relatively speaking. Of course, by that I do not mean any very precise relationship except the general effect would be the same.

R. D. Q. 1789. But the effect of the ground would be the same in both cases illustrated on the chart, wouldn't it?

A. Yes.

R. D. Q. 1791. And the chart is for comparative purposes?

A. The chart is for comparative purposes.

R. D. Q. 1792. Will you read into the record, please, the conditions of the ground assumed? I think you will find them on the back of the chart.

A. The diagram shown on this exhibit for defendant's antenna No. 8, at .49 lambda above ground, the ground [fol. 487] having a conductivity of one-tenth times ten to the minus 13 electromagnetic units and dielectric constant of 7. That is all.

Mr. Darby: Mr. Blackmar, you asked for the formula. I hand it to you. I would like to have the record show it has been supplied. That is all.

Recross-examination.

By Mr. Blackmar:

R. X Q. 1795. Mr. Kelley, it seems to me that the record may show the same thing with respect to this chart, Exhibit HH, that I pointed out yesterday—I think it was in connection with the prior similar exhibit. Did you mean, when you stated that what was shown on this chart applied also to all the other of defendant's V antennas with the exception of antenna No. 2 rebuilt, in respect of the difference in angle of maximum radiation over ground and with respect to the width of the beam over ground?

A. No, sir, with respect to the length of the lobes shown on the right-hand part of the diagram drawn in the maximum direction.

R. X Q. 1796. Did you mean that in each of defendant's antennas outside of No. 2 rebuilt there is a greater maximum length of the lobe in that direction than there would be using the Carter angle over the same ground?

A. Yes, sir, I haven't had them calculated, but the angles have been chosen so that such a result would be reasonable, and I am sure it would be checked on calculation.

R. X Q. 1800. Is it not true that in both the case of the single wire and of the V, that under the image theory there is an image in the ground of whatever is above it,—[fol. 488] of the entire antenna system?

A. That is entirely correct, sir.

R. X Q. 1801. So that in the case of the single wire above the ground the image is of one wire, is that correct?

A. Yes, sir.

R. X Q. 1802. And in the case of the two-wire V antenna the image in the ground is an image of two wires, is that correct?

A. Yes, sir; it can easily be visualized in terms of the optic nerve, it is what you see by reflection.

R. X Q. 1804. Where there is a horizontal V antenna of two wires, and we will assume that the bisector is in easterly and westerly direction and that the one wire is on the southerly side of the bisector making an angle of 22½ degrees with the bisector, and the other wire is on the northerly side of the bisector making an angle of 22½ degrees also with the bisector, will you tell me approximately the angle of principal radiation of the system with respect to the southerly wire in that case?

A. I would be glad to do so, but I don't recall having said anything about that in my redirect examination. All I referred to was what I assumed in respect to conditions, and that was that this was in free space, nothing more thar that.

R. X Q. 1805. I want to take you down now so we are assuming that the V is set up over ground as the defendant's antennas are set up.

A. There would be different angles, and I can't tell you offhand what they would be.

R. X Q. 1806. What would be the difference in angle of the beam of principal radiation with respect to one wire as compared to the angle with respect to the other wire in that case?

A. You mean considering this beam not in the plane of [fol. 489] the wires any more, but at some angle to the wires, it would form two different angles of the same magnitude, but on opposite sides of the direction of principal radiation.

R. X Q. 1807. That is, the angle of principal radiation in one case might, for example, be 30 degrees with respect to one wire, on one side of one wire, and it would still be 30 degrees with respect to the other wire, although on the other side of it, is that what you mean?

A. Yes, sir, on the other side of it.

Mr. Blackmar: That is all.

Mr. Darby: That is all, Mr. Kelley, thank you.

Robert Meade Sprague, called as a witness in behalf of the defendant, being first duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

The Witness: I reside at Sayville, Long Island. I am employed by Mackay Radio & Telegraph Company, and have been for approximately three years, in the capacity of Engineer throughout all that period of time. I am located in Sayville, at the Sayville plant. I am a part of the staff that has charge of the Sayville plant, the transmitting plant.

I am familiar with the circumstances under which antenna No. 2 was rebuilt. They were as follows: We received an order from our New York office on the morning of September 9, 1934, to dismantle the original No. 2 antenna, which [fol. 490] was being used on a frequency of 147.40, for Europe, and to erect an antenna for 'Frisco on the same poles that were already standing, turning this other antenna in the general direction of 'Frisco. This work was completed in one day and one night, and was put into operation the following morning. That antenna was operated approximately three months, intermittently.

To refresh my recollection I have consulted the official records of the company. The use of that antenna was discontinued in December of that same year, 1934. There has not been any use of it since that time. It is not in a condition for use.

Andrew Alford, called as a witness in behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

The Witness: My full name is Andrew Alford. I reside in the City of New York, Manhattan. I am employed by the Mackay Radio & Telegraph Company as an engineer.

My technical education, in so far as higher mathematics are concerned, was as follows: After graduation at the University of California, I studied at the California Institute of Technology, and I was a Teaching Fellow at the Institute of Technology for about a year and a half, and Dr. Milliken was then the Chairman of the Executive Committee. One of the subjects I taught was advanced calculus, and another one was analytical mechanics.

[fol. 491] As to the nature of my employment as engineer with the Mackay Company, one of the things that comes under my jurisdiction is the design of antennas and various calculations connected with it. My jurisdiction is not confined to work of that character only as affecting United States work; I am quite frequently called in, practically always, as a matter of fact, whenever there is a question in connection with an antenna design in some other country

where the International Telephone and Telegraph Company or its subsidiaries might want to erect an antenna.

I personally drew these drawings on these two sheets, Defendant's Exhibit A,—traced them as a matter of fact. I traced those curves from photostats of curves found in the file wrapper of the Lindenblad patent, No. 1,927,522.

I personally checked charts which have been marked in evidence in this case, Defendant's Exhibits E, F, G, S, T, X, Y, Z, BB, CC, DD, FF, GG, HH. Some of them I calculated myself. I believe they are correct.

Cross-examination.

By Mr. Brown:

The Witness: I have been with the Mackay Company about two years.

X Q. 18. And how long have you been working on the preparation of this case?

A. Well, I don't know just what——

X Q. 19. Most of the two years, haven't you?

A. No, I don't believe so.

X Q. 20. How long did it take you to make these calculations?

A. Well, some of these calculations, of course, were made a long time ago.

X Q. 21. By you?

A. Some of them by me, yes.

[fol. 492] X Q. 22. What do you mean by "a long time ago", two years?

A. I don't exactly remember.

The Witness: There were a number of mathematicians working under my immediate supervision, however. I had several young engineers helping me to make these calculations, graphs, and so forth.

I am quite sure that all of these calculations and graphs put in here are correct, even though I had other mathematicians help me, because I checked them with as much care as one possibly can use.

As to whether I know anything about antennas practically, I have adjusted antennas, I have designed them, and I have tested them.

The graphs I have produced here and identified are not mathematical analyses pure and simple, so far as I am

concerned. I may add this, that a calculation of this sort gives you an answer to a practical problem with a considerable degree of accuracy.

Redirect examination.

By Mr. Darby:

The Witness: I either personally calculated or checked the calculations from which the models, Defendant's Exhibits O and P, were made.

Edmond Bruce, called as a witness in behalf of the defendant, having been duly sworn, testified as follows:

Mr. Darby: The notice under which the testimony of this witness is offered reads:

"In connection with the above suit, I hasten to give you the necessary data in connection with the additional items [fol. 493] of defense that will be used at the trial as soon as the information thereof was uncovered and made known to me.

"As to the two Lindenblad patents and the third Carter patent (of the Supplemental Bill), prior invention, prior knowledge, and prior use of Edmund Bruce and/or Bell Telephone Laboratories of and at New Jersey."

Direct examination.

By Mr. Darby:

The Witness: At the present time, I live at Red Bank, New Jersey. I am a research engineer for the Bell Telephone Laboratories.

My technical education was as follows: I was a technician in the United States Navy, from 1917 to 1919. Following that, I spent a year at George Washington University. Following that, I had four years at the Massachusetts Institute of Technology, where I graduated with the degree of Bachelor of Science in Electrical Communications.

In the fall of 1924, I went into the engineering department of the Western Electric Company, which later was reorganized into the Bell Telephone Laboratories. Throughout that period of time I have been research engineer. My

particular efforts have been in the direction of short wave radio communication.

While there, I believe I devised what may be termed a rhombic antenna. I consider myself to be the inventor of that type of antenna.

As to the circumstances under which I made that invention: Excluding the work that is not material—assuming that you are interested in antenna developments—I will [fol. 494] begin there. I was first interested in what was required to improve short wave communication.

I appreciated, after experiment, that to overcome the inherent noise in receivers, it was necessary to get more energy output from the antenna systems—that was my first object.

My second object was to develop directive antennas, and in so doing, it was hoped to improve the ratio between the signal received and the extraneous static and other interferences.

The third object in the work was to develop a means which satisfied these preceding two mentioned objects, in a manner that was as cheap as possible.

I think those are the three principal objects of this work.

In order to find prior art among others, I was interested in the development of the prevailing theories on the so-called wave antenna, which is the use of long waves, prior to my time, of working on this problem.

In reading that material, I was taught that a wave antenna was a long wire extending in the direction of the distant transmitter, substantially horizontal, and that the antenna relied on the so-called wave tilt for its operation and had not this wave tilt been present, the antenna would not be very useful.

It is known in the art, and I have checked with my own experiments, that there exists a surface wave—by that I mean a wave traveling over the ground, and that is what we call imperfect, and I mean by imperfect, that the dielectric constant and conductivity are both lower than the extreme optimum values, and the surface wave in traveling over such earth is retracted at the foot, producing a wave tilt.

[fol. 495] I was taught by what I read regarding wave antenna operation that it was this wave tilt which produced the useful component in wave antennas.

Having this knowledge in mind, I proceeded to some of my earlier experiments.

I have in my hand here a photostat of an original record in my own handwriting which I made on May 13, 1926.

The second sentence is of importance:

"The following antenna comparisons with a loop were made."

I shall explain that. In order to determine whether an increase in energy was obtained we wished some fixed standard of comparison, and as we made various experiments we would refer back to that standard, and in that way we could measure the degree of improvement.

The layout of the sytem, I find under the heading:

"Entire tests of distant oscillator output constant," meaning by that that there were no corrections to be made for changes in oscillator output to a frequency, say, of 12.2 times 106 cycles per second, approximately.

On this paper I have a series of columns. On the left-hand side are the series of antenna arrangements used. It starts with a small loop antenna, to which I referred before, which is a reference for all these comparisons.

There are three other columns on the right-hand side of the paper. The two columns on the extreme right refer to the amount of inductance and the amount of tuning capacity that were used in the particular experiments. The only reason that is for is to show that the proper point in [fol. 496] which resonance was obtained, and also the attempt to match impedances, which is also known in the art, that in connecting two pieces of electrical apparatus together, it is desirable to match the impedance.

The important column there is the one just to the right of the figures, which reads: "Attenuation for constant output." I might say that this requires explanation.

I have partaken in the development of measuring apparatus whereby the essential scheme is that a deflecting meter on the output is always kept to a constant deflection on all signals with the means, in that apparatus, whereby, where the application ratio can be changed in known amounts.

The column listed here is intended to convey the idea of voltage ratios that were in a resistant attenuator, which lowered the gain of the set.

One can judge the result by the magnitude of these figures since the output was constant. The judgment is to be made by comparison of these numbers, the higher number representing the greater output attained.

Now, as comparing the various sets of antennæ involved, in the comparison loop antenna, which is indicated here as being a two turn loop, it makes no difference what size this was, so long as the same standard of comparison was used throughout, the attenuation was set for a ratio of 10.

In relation with my reading on the operation of wave antenna, I constructed the system which is indicated just below that, to constitute a receiver, constituted of a wire that was substantially horizontal and that wire was .125 wave lengths in length, from the same receiver diverging from nearly the same point.

[fol. 497] There existed a second wire besides this one I mentioned as being substantially horizontal, a second wire of the same length and diverging from closely to the same point at the receiver up to a separation of the far end of .112 wave lengths.

Under tests with that, as mentioned previously, with the distant oscillator at a constant output, and with the test receiver with a fixed gain and fixed output, the attenuator now read 75.

And the further columns indicate the inductance and capacity that was used for tuning that.

Confining our attention to the attenuation of 75, that means that where the ratio of signal thrown away was now 75 times, in the previous case, it was ten times, therefore, this is, in voltage ratio, 7.5 as good as the loop that was used as a standard of comparison.

Now, proceeding to another test which is indicated directly below that, here the wires are in the same general form, except the wires are increased in length. The length of each element is now .25 wave lengths, the spacing at the far end is the same as before.

The idea of this test being what effect it had when we increased the length of the wire, other conditions being constant.

By the attenuator setting we see the column of 68, which is, as we compare that with the 75, a result which was not quite as beneficial as the preceding one.

Proceeding to the next diagram below that, here we have the same length of wires as discussed just above.

The only change that was intended in the layout was that the far end, where previously it had been .112 wave lengths in spacing, is now .25 wave lengths in spacing.

[fol. 498] There are several numerals indicated here, the difference between those numerals being this: that the inductance seen at the center column, one, two, three and four turns, and the right hand column indicate the difference in the capacity of condenser which indicates resonance.

What is intended to show there is that an attempt was made to match impedance between the antenna and the receiver proper, and we selected for comparison the optimum result obtained there and, as I look through, I see that 95 is the larger of the attenuator settings. Therefore, as all other conditions were intended to be either the same as in preceding experiments, we now compare the 95 with the preceding figures of 68, 75 and 10, which, of course, it exceeds, therefore, this is the better arrangement than any of the previous ones tested.

We note that the difference between this and the test immediately above is that there is just a greater divergence of wires at the far end. The difference between this one and the system, which is the two by four, the one under discussion, is that the wire is longer and the spacing is greater. So far this is the best arrangement discussed.

In an attempt to be logical, proceeding further in the tests in orderly steps, we now used the same general arrangement, but the length of the wires now is .5 wave lengths long, the spacing is the same as used, the spacing at the far end is the same as used in the preceding tests. Again looking at the column for attenuation I see figures of 70 and 58 obtained under various conditions of conductance, impedance matching, and so forth. I think both of these are inferior to the 95 previously mentioned. Therefore this is [fol. 499] evidently not as good as the preceding case, in spite of the greater wire length.

As a further experiment, the same arrangement was used except at the far end, instead of being .25 wave length spacing between the ends it is now .375. Here I see that the attenuation, other things being equal, is recorded as 75 and 62. Here again 75 does not appear to be as good as the 95 that I mentioned above.

This record is in my handwriting. I made it on May 13, 1926; it is dated at the top of the page. I had the original record in a notebook in my possession. It has been con-

tinually in my possession from that time except such times as it has been in the hands of an attorney. This record is a record of what I have done; also the first arrangement here is I consider an outline of what I intended to do. The physical work I did at this time by myself.

On May 14th, the following day to the one just discussed, the experiments were continued. From day to day we can't necessarily expect the gain of a receiver, of an oscillator output, to remain the same. As we do not necessarily expect that, a test was made to see that it did, and I see that for the very same set of conditions on the loop that the attenuation constant was again 10. Therefore, the attenuations that I read are directly comparable to the previous page.

I see here a notation which hasn't been indicated on the preceding drawing, that the distant oscillator on which these tests were made is indicated here as being four wave lengths away. Evidently it was the same thing the preceding day. I am judging that now because I produce the same results, using the loop antenna.

[fol. 500] Proceeding with the experiments, we got a certain encouragement increasing the length of the wires, and it is quite obvious that for any given length of wire there is some divergence, or in other words, some spacing at the far end that appeared to go with that length of the wire. That is the teaching in the experiments so far.

So the next step was to take a comparatively long wire and see what the results would be. These tests were conducted in the same manner as before, but now our wires are 2.25 wave lengths long, and the far end spacing is .375 wave lengths long. I believe that was the limit that was possible on the comparatively small pole that was used at the time. The setting for the attenuator here was 150 for two sets of readings, evidently two methods of tuning give approximately the same impedance match, and therefore got much the same effects. But the important point is that the 150 is in excess of any other attenuator setting that I have mentioned, therefore this is a better arrangement. All of which indicates that as I increased the length of the wire I got an improved result.

I evidently did not further attempt to increase the spacing at the end of the wire on account of the restriction of the poles that I had available.

There is one thing that I want to be certain of, though; as I made the wire considerably longer in this experiment than the preceding experiments I found that the far end of the antenna was getting rather close to the test oscillator which is indicated here as four wave lengths away compared to the length of the wire, 2.25 wave lengths. In order to get a further check of what the results would be had the oscillator been further away, I have drawn in the [fol. 501] third test indicating that the conditions are the same as previously, except that the oscillator is moved four wave lengths from the far end of the antenna rather than four wave lengths from the receiver. I see here that the attenuator setting for this condition was 48.

The importance of these two tests will be seen in what I have to say which follows:

I mentioned previously that one object in my work in antennas was to get more energy output from the antenna, which I believe indicated that by a proper length and angle here one might achieve such a thing.

A further object which I have previously stated was to get directivity in an attempt to reduce static and other interference. In order to test that, the oscillator was moved in stages around the antenna in a horizontal plane, and that is what I intended to indicate on the figure on the lower part of the page. That figure is intended to be a top view of the directional characteristics as written. If you will look at the various conditions, there are circles here with crosses in them. Those just merely indicate the position at which the test oscillator was placed for the tests involved. For example, there is a circle near the end of the top view of the antenna where it says alpha equals 150. Incidentally, alpha in this work was my symbol for the attenuator setting.

It appears quite dim in my photostat, but there is drawn here a vector which was intended to show that three of these spacings were all spaced four wave lengths from the receiver, one in front, one behind, and one alongside, all viewed from the top. The one in front, we say that alpha [fol. 502] equals 150, which I would like to point out is mentioned above as being 150 in the second test involved.

Those are the same conditions. That 150 can be compared with the backward direction. The oscillator was placed in back and I have it that that indicated at 38, so if

this is a fair set of conditions of directivity, in a forward direction my attenuator was 150 and backward 38, and the ratio between those two indicates the tendency toward unidirectional characteristic.

However, as I mentioned before, as this oscillator is getting fairly close to the far end I wanted the test condition to be perfectly fair, so I have taken another condition.

I moved the oscillator so that it is four wave lengths from the far end instead of four wave lengths from the receiver and I also noted that the backward position of the oscillator is four wave lengths from the receiver; in other words, an equal distance from the extremities. As we compare them under these conditions we find them to be 48 as against 38 in back, which indicates there was nothing improper in the experiment in relation to the addition of the oscillator.

Again, as 48 is larger than 38, this system tends toward unidirectional characteristic.

So much for the forward and backward direction.

Now for the sideways direction, the oscillators were placed both four wave lengths in broadside direction, or, I should say, perpendicular to the plane of the wire, and perpendicular to the plane to the ground through this wire. There was placed four wave lengths beside the receiver and also four wave lengths beside the extremity of the [fol. 503] antenna. At four wave lengths beside the receiver the attenuation was 10.5, which is considerably less than any other value that I mentioned.

Also, when the oscillator was placed four wave lengths beside the far end of the antenna, the attenuation was 8, which is still a small number compared with 48.50 or 38, indicating that the radiation sideways of this system was small compared particularly with the forward direction and also with the small backward directions.

I see I have written in the bottom of the page here, May 15, 1926, and the following day I went to New York to make an application for a passport.

At this stage of the work I was given work that does not pertain to this, and which called for a trip to England, and I think in the following month I left for England. I was temporarily putting aside this work until my return. Here is a sheet which I have dated on the top May 14, 1926, and the second paragraph reads: "It is definitely decided that I will sail for England with Southworth and

Hubbard about May 27th. Telephone to see what is necessary to get passports. Wilson recommends that I do this tomorrow." Southworth and Hubbard were fellow employees. I went to England as planned. To the best of my recollection, but I would say I was away possibly a month.

These two pages dated May 14th are both entirely in my handwriting. They were made on the dates indicated at the tops of the pages which I have mentioned in their description. The entry at the bottom of one of the pages was made on May 15, 1926.

[fol. 504] I disclosed this work that I had been doing; I mentioned reading material pertaining to the operation of the wave antenna, so-called wave antenna, used in long waves. I obtained this material from memoranda and clippings from publications which were in the possession of Mr. Englund, one of my associates in the Bell Telephone Laboratories. During the process of these tests, if my recollection is correct, on May 14th, I described to him the tests which I had undertaken. It is my understanding that in his personal notebook he wrote down a sketch of the layout and the dimensions of one of the arrangements I have discussed. I have seen it at a later date.

The Court: You saw at a later date something he purported to have put down at an earlier date. You don't know that he put it down on the date that he said he did?

The Witness: I don't know that he did it on the date he said.

The Court: No, but you saw something at a later date which he purported to have put in his book at an earlier date?

The Witness: Certainly.

The Witness: On returning from a trip to England, and clearing up other matters following that visit, I again took up the subject. It seemed to me that the experiments indicated that for various lengths of wire there was an angle which gave an optimum result. I wished to, in my own mind, decide on the theoretical reason for that. On September 28, 1926, I have a record of what I thought was a plausible reason for the effects I had achieved. I have here [fol. 505] a plot of various lengths of wire, each wire laid out at an angle in relation to an assumed wave direction which is drawn here, which seemed to me a reasonable ex-

planation of why there is an optimum angle for each length of wire. It is also intended to indicate that there is a possibility that the longer the wire the more output I could expect from the receiver which was indicated in the experiment at least as a trend because the longest length of wire was the highest attenuator setting that I mentioned.

This is laid out on this spacing. Starting with No. 2 vertical wire, and gradually increasing its length, each time the length is increased, there is a rematching of impedance to the receiver—one continuously gets an increase in output up to the point of a half wave length. Beyond this point, by a small amount, why, the energy again decreases.

I have indicated on the right here a vertical line whose lower extremity is at zero and its upper extremity at .50, indicating half a wave length in length, and the wire vertical.

Analyzing the effect in such a wire, it appeared to me that voltage induced in the very far end had to travel down that length of wire to reach the receiver, and as the wire is half a wave length long, it is a half a period out of phase. This, of course, is an approximation. It is reasonably close, however.

Now, if we make that wire longer, the reason that we achieve the reduction of output is because it is beyond the half wave length. I might further explain this: that half wave length can be represented by a series of vectors tracing a semi-circle, and the resultant series of vectors tracing a semi-circle is a diameter.

[fol. 506] Now, should one extend the circle by a small amount, the points connecting the start and finish is less than the diameter. If you continue that far enough, the circle closes, and there is no resultant. Therefore, the maximum amplitude is substantially a half wave length.

Now, I am trying to convey on this paper, from this point on, that the far end of the antenna should be a half period out of phase in respect to the receiver, as the lower end of the antenna is at zero.

Now, if we make the wire longer and less energy, that is a disadvantage, but it seemed to me that I could advance the upper part of the wire into the wave direction, thereby getting an earlier sample of the wave, so to speak, and alter the phase relation such that I could still achieve the rule of having the far end of the wire have a period out of phase with the one end of the wire.

I have drawn on this paper a series of wires which follows that layout.

For example, one of the longer wires has indicated on its extremity one and a half, which indicates one and a half wave lengths. We drop a perpendicular down on the ground, which, incidentally, in this case, is assumed to be the wave direction, and we find that its distance from point O is one wave length. The projection on the wave direction as indicated is one half wave length less than the wire length. And that rule has been followed out in plotting all these various lengths of wires.

Mr. Darby: Mr. Blackmar wants to mark for identification the formula that we supplied him. I have offered to offer it in evidence instead as a defendant's exhibit.
[fol. 507] The Court: All right.

(Marked Defendant's Exhibit II in evidence.)

The Witness: On the exhibit of September 28, 1926, I had completed my description with the exception of a notation that I have in the lower right-hand corner, which says:

"Witnessed copy in possession of J. H. Couzens, Patent Department."

To the best of my knowledge I discussed this with Mr. Couzens a few days after September 28, 1926.

Mr. Couzens is an employee of the company; he is in the Patent Division. To the best of my recollection I discussed this on October 9, 1926, with Mr. Couzens. I have no knowledge of what became of the original witnessed copy referred to in the copy now in my possession; that would have to be obtained from Mr. Couzens.

The Court: Did you keep it or give it to Mr. Couzens, or what did you do with it?

The Witness: Mr. Couzens took it with him.

Q. 45. On this sketch it is annotated that the ground is shown in the conventional character of lines as well as the word "ground." Will you state whether or not in making that sketch you considered actual ground or perfect ground?

A. In a sketch of this type the important thing is the relation of the wire with the direction of the wave. How-

ever, perfect ground is intended in this case to fit that assumption.

Mr. Darby: I offer in evidence a photostatic copy of the [fol. 508] chart just described by the witness.

(Marked Defendant's Exhibit JJ in evidence.)

The Witness: The next sheet I have before me reads at the top "Daily wire measurements at Deal on 14 meters, July 19 to 21, 1927, small transmitter at a distance measuring set No. 6." As indicated by that sentence, a small transmitter was placed at a distance; there was a tall pole available at Deal, so that the wire could be suspended; running from a pulley at the top of that pole was a rope, and I am explaining that, in that various lengths of wire were used in this experiment, but in all cases slack was pulled out by means of the rope.

The diagram in the center of the page indicates the distant transmitter by the box marked T. The receiver is in a box marked R on the right. The pole is indicated there. The solid line indicates the position of the wire. There is a dotted line on the other side just merely to indicate, as marked below, that I have referred to, as distance either toward the transmitter or away from the transmitter measured from the base of the pole as either plus D or minus D. I believe that notation appears in the data.

Going to the numerals written above this sketch, the first column is "Antenna length." I mean by this that this test was performed at the constant wave length of 14 meters as indicated on the top. We put up one length of wire, tested it, tore that down, and we put up another length and went through successive tests in that fashion.

[fol. 509] The next column labeled "Output deflection" shows 100, which is intended to represent microamps in all cases.

The next column is labeled "T. U." We have this in order here to explain that this differs slightly from previous testimony, in that there I had expressed it in voltage ratios. It is standard in communication work to express voltage ratios as, in those days, transmission units. Today we call it decibel and there is very little difference. "T. U." means "transmission unit", and it represents the ratio just to give a general idea of what is intended. One DB variation means a ratio between two numbers which differ by only approxi-

mately ten per cent. I am just saying this to illustrate the magnitude of the DB and of the TU is roughly the same thing. They were called transmission units at that time.

Again as before, the degree of the number represents the indication of what output was obtained at the receiver. There is no difference in that. We are just using the T. U. which is at a logarithmic arrangement rather than the previous ratio mentioned.

The next column is "Optimum Coupling". Here the notation is the same that I explained previously, the denominator indicates the number of turns in the inductance coil while the enumerator indicates the number of turns from the ground position at which the tap was used.

In all cases, the various tapping positions were used, and were always tuned to resonance. This is with the view to match impedances between the antenna and the receiver, something which is always necessary or the results do not mean a great deal.

[fol. 510] The next column is entitled "Horizontal Distance of Tilt."

There are several figures mentioned. All except the last and the first one are indicated in the minus directions, which, when we look at the diagram means that D indicates the direction from the foot of the pole, removed from the distant strength transmitter.

The final column is labeled "T. U. Improvement."

The nature of the unit T. U. is such that where previously our ratios were either multiplied or divided with each other as T. U. is logarithmic, a logarithmic relation, we are permitted to add and subtract them, and it makes T. U. a very convenient unit.

Therefore, for example, the first item in the last column is a dash which I will explain. The next one is 2.1. It is intended that 2.1 will be the difference between the two readings under the column labeled "T. U." about the center of the page; and so forth.

Without going into too much detail regarding this, we see a progressive increase in the length of the wire. In each case, the increase at which the wire inclined to the wave direction was altered by varying the dimension D, which is the distance from the foot of the pole; in all cases, regardless of the length of the wire, the slack was taken up by means of the rope structure, so that the wire was always taut.

If we now take the length of wire which is represented in the left-hand column and the column of T. U., we get the substance of the experiment; I will explain, as these columns are mentioned.

[fol. 511] Starting with the half wave length, lambda over 2, which is the indication for half wave lengths, the position of the attenuator on the receiver is 8.8. Now, all conditions are supposed to be altered where you get the optimum for that length of wire, I mean the angle of tilt, the matching of impedance and tuning and so forth. By going to the one wave length wire, we see 11.9, again, everything was done to get the optimum result. And we see that that is slightly better than the half wave length wire, so we get a better result by changing the length of the wire and readjusting the tilt angle.

Following that, we have a wire length of two wave lengths, and the result is 17.5, that is again better. Then, at four wave lengths, the result is 20.5. In other words, provided that in each case we select the proper angle and did the various other things which anyone skilled in the art would do to optimize the result, we find a progressive increase in the output of the receiver as the antenna length is increased.

I see down in the last item in these columns a similar notation of four wave lengths, but on the column labelled at the head, "Horizontal distance of tilt," it says: "Plus, less than 150 feet." What is meant by that is, we went on the other side of the pole. There was a suspicion that there might be a bi-directional characteristic to that sort of thing, or due to reasons which we appreciated at that time, such as attenuation along the wire, there may be a tendency toward the uni-directional characteristics, and that is what this test was intended to indicate. We see, when we put the receiver on the side towards the transmitter, the T. U. [fol. 512] drops from 20.5 to 18, and that indicated clearly that in spite of moving the receiver closer to the oscillator, the conditions of the experiment were such that we got less energy where one would expect more energy under those conditions. But that was due to the tendency toward unidirectivity in the wire under test.

So this expression shows us that is really an attempt to check what I have stated previously as a conception of length of wire and tilt of that wire, to go with it. The tilt is

measured between the wire in the direction away from propagation.

All the entries on that page are in my handwriting. They were made certainly at or before the latest date indicated above, which says July 19th to 21st, but I am certain that it is either July 21, 1927, or prior to that.

In the various antennas that I used and concerning which I have thus far testified, the antennas were open ended. The antennas on my note of May 13th were open ended. And my antennas on my note of May 14th, were open ended.

Referring to my diagram which is in evidence as Defendant's Exhibit JJ, all of the entries on that are in my handwriting, other than the stamp up here which evidently was put on here by somebody else. I made that record on the date indicated above which says September 28, 1926.

Q. 57. Now, I hand you a sheet of paper, and I ask you whether or not you recognize any one or more of the mathematical formulæ thereon written, and whether or not you ever checked the work represented on this Defendant's Exhibit JJ, with any one or more of those formulas.

A. In a quest of this type, I, of course, do not memorize these formulas. I, however, do recognize the general form of them.

[fol. 513] You have certain symbols in here which I can only assume their meaning, but I understand the third formula here—it may be that I am accustomed to using complementary angles to the ones expressed here.

I appreciate when that is done one can interchange sines and cosines, and it is perfectly permissible. If someone can say that this is an accurate formula, I recognize the general form.

May I refer to my note book to refresh my memory?

A formula of the general form which I believe is under discussion was noticed by me in an article in the Institute of Radio Engineers. The article is by Levin and Young. The sheets I have here, I am searching for the date of publication, which I don't see. However, it says in a footnote below, "Received by the editor January 13, 1926." Whenever that was published, I judge in 1926, I saw the article shortly afterwards, and attempted to digest, and I believe that I saw in that article an equation that is of the general form you have here. Incidentally, this is not an

equation. It seems to be one term, there is no equality sign, and so forth.

Q. 62. Which one or ones of the sheets that I handed you does the formula mathematically resemble the formula that you saw in that article?

A. I find a formula on page 7 of this publication, labeled "Formula 15." I see by the notation above, it says, "Section D grounded antenna." The final term of this looks very similar to the one you have written on the paper here. I will read it:

"Cosine (Beta cosine theta)."

[fol. 514] That is all in the numerator. In the denominator, there is "Sine theta."

The principal difference I see between these two is they have used the term beta, and the formula that you have handed me uses in its place pi N over 2.

Looking elsewhere in this publication, on the bottom of page 6, they define beta as pi over 2 times N, which, I believe is the same thing with the exception that you have got a subscript to that, sub zero, where it is here just theta, and I imagine it is a similar reference.

Mr. Darby: I will offer the sheet in evidence.

(Marked Defendant's Exhibit KK in evidence.)

It is my understanding that the formula under discussion was derived under conditions of a wire being vertical, erected over perfect ground. The wires which I had made tests were inclined at an angle over the ground which was not perfect. I am not inclined to believe that this formula fully explains the results which I have seen.

The next record I have before me is written in my handwriting, with the exception of a witnessed signature on the bottom. It is dated August 2, 1937. I will read:

"Using one of the long tilted wires as an element"—may I pause to explain in this testimony that there is a vast amount of work in between the various instances that I have discussed here and the subject of tilted wires has been [fol. 515] thoroughly investigated by experiment and calculation, and with that known, this evidently is the next step in the conception.

I will read again, "Using one of the long tilted wires as an element it is desirable to find methods of using them in

arrays. Economy demands first studying the combinations which require only one supporting pole.

"The simplest scheme is shown below."

Below that is a sketch.

In the sketch we have indicated ground with a pole which is upright. To the right of that pole is what I have been terming a tilted wire, the same general form as previously discussed.

On the left hand, opposite the pole, there are dotted lines. What I intended by this sketch is to indicate that a second line should be added to the first element and getting a cumulative relation between the two.

There is a vector diagram below the sketch which refers to the center point of each wire and to those skilled in the art explains the cumulative relation. Under the condition of the direction a wave assumed, the length of the wires and their disposition as to angle, these vectors indicate that the two elements are cumulative in their result at the receiver.

I read further down the bottom, "It is seen that the tilts of each element are maintained the same as if they were alone. It is also seen that with the above arrangement no radiation can take place in the YZ plane."

By YZ plane is meant a co-ordinate system where the X dimension lies in the plane of the paper and horizontal, the [fol. 516] Y dimension lies in the plane of the paper and is vertical, the Z dimension is perpendicular to the plane of the paper; therefore the YZ plane is that plane which is perpendicular to the paper in passing through the fold. There is a notation here, which has been added since the original record was made. I refer to that in the middle of the page, which has my initials, and the date of 8/8/29. I will read the note. It says, "More vector points along the wire are necessary to show this last case". That note was added when going over all my previous work I was preparing a publication and while I found these vector relations are correct, to be convincing, why additional vectors should be added to make it prove convincing.

On the bottom of the paper I see it is signed with my signature on 8/2/27. In the left-hand lower corner I see the signature of Mr. H. T. Friis also on 8/2/27.

With my recollection refreshed by what I find on this paper I can state that I disclosed the subject matter to Mr. Friis on that day.

Q. 68. With reference to this page dated August 2, 1927, is everything on that page in your handwriting with the exception of Mr. Friis' signature and the date, that is, the date over Mr. Friis' signature?

A. That is true; with this exception. I see in the upper right-hand corner it says, "Exhibit D", which I did not write. Also under the diagram I see a dimension which, while dull, appears to be, "lambda over 2 between the pole and the receiver". I did not write that. Other than that, I believe everything is in my handwriting with the exception of Mr. Friis' signature. I do not know who wrote lambda over 2 under that diagram.

[fol. 517] The next record I have is dated August 9, 1927. It is evidently an attempt to confirm the conception which has been just described. I see by the sketch at the top, just for purposes of variety, we are no longer connecting the receiver to the antenna, but this time we had it connected to the transmitter, and the receiver was placed at a distant point. It is recognized by those skilled in the art by a theorem which we call reciprocity that the behavior should be the same if the transmitter and receiver are interchanged. In order to get this directly into an experiment I chose to interchange that in this particular case.

Also I see another variation from previous modes of testing in that where previously we had used a fixed wave length and varied the dimensions of the antenna, I have chosen here to use fixed dimensions of the antenna and vary the wave length. There should be, if this is properly constructed, there should be in the range the same behavior as I had hoped for in the conception previously discussed.

On the top I see that it reads 42.9 meters equals 141 feet. There is a similar label written directly above the wires of the sketch, meaning to indicate the length of wires.

I see here also in the upper left hand corner phi equals 58 degrees. Phi is indicated in the drawing as being the angle measured between the wire and the pole.

Referring to the various columns under the sketch, the left hand column reads "Transmitting condenser."

There is a series of numerals of equal increment which just merely mean that we progressively changed the wave [fol. 518] length of the transmitter. For convenience, the antenna current was recorded. Should this antenna current vary at all, why, a correction should be applied to the results. In general, the variations, with one or two exceptions, are not great.

There is another column labeled: "Receiver condenser" and that is for the operator's convenience and is of no interest here.

The next column is "Wave length." That is important, and I will refer to it.

By this change in the transmitter condenser we have changed the wave length, as indicated in this column.

Now, there is a column marked "Deflection". Here, for instance, on the top of that column, it reads 52 minus 33 equals 19. What was intended by that is the effect the receiver had on the output and deflecting meter, in which there was the initial deflection when there is no energy being received. In each case the initial deflection was subtracted from the total deflection which resulted, and therefore there is no need of paying attention to the figures except to those to the right of the equality sign.

As I go down and examine the numerals to the right of the equality sign I see variations until I reach one that reads 131. That, I believe, is the largest deflection there. To the right of that I notice the word "optimum".

Going to the right hand column it says "Wire length and wave lengths." Naturally knowing the wave length which is the subject of one of these columns and the length of the wire element as measured in meters, I should say that this wave length was measured in meters, then the wire [fol. 519] element was measured in meters, and one can obtain the wire length in wave lengths, and it was supposed to be the subject of the column to the extreme right.

And for the one that is recorded as optimum, I see that the wire length of each element was 2.28. Therefore, by experiment, we found an optimum condition under the conditions of the experiment.

Further down on the sheet there is indicated a test of directivity, as in previous measurements we were concerned with getting not only the largest output to overcome the residual noise in the receivers, and when I say "receivers"

it makes no difference whether the antenna is connected to the transmitter or receiver.

And another object which I have previously mentioned was to obtain directivity to discriminate against static. This lower test is intended to measure the degree of directivity that was obtained—I hope directivity will be taken as a general term—in an attempt to measure variations in different directions at a constant radius.

Here I have chosen to measure the distance of the receiver from the pole of the transmitting antenna at 60 paces away, a pace being approximately three feet.

This is intended to be a diagram looking down from the top, or a plan view. The oscillator is moved from point to point. As indicated, where the figure reads 121 for the deflection, the receiver was directly in front of the antenna.

Going down, at right angles to that, I see a dot which is supposed to indicate the position of the receiver and marked a deflection of only one, which is very much smaller, indicating that there was considerable degree of directivity. [fol. 520] There is very little sent sideways, which proves my contention expressed previously when discussing all of these two 1927 exhibits, that no radiation can take place in the YZ plane. I think that this checks that contention.

There are intermediate points between those two with varying deflections, all of which are less than 121.

This test appeared to me to check that I was achieving in directivity what I had hoped for under the conception.

There is one other point here regarding the node at the bottom. I will read: "Note theoretical phi for optimum L equals 2.28 is phi equal 51 degrees."

Taking that 51 degrees and comparing that with the 58 degrees mentioned as the angle at which the structure was laid out, the 58 degrees being in the upper right-hand corner, there is a discrepancy of seven degrees.

I would like to point out that in all such experiments, there are several factors which I have called in my work "Correction factors", to the main principle under which things operate. I have previously explained that when one works with a local oscillator in the vicinity of your receiving equipment, you have to deal with what has been called a surface wave, in which there is a wave tilt or the foot of the wave next to the ground lags. Now, if one could assume

that such a lag was seven degrees in this case, we would get a perfect check of the angle theoretically.

I do not pretend for a minute to say that that is the only factor involved here, because there are a number of factors [fol. 521] in such a test which affect the accuracy of an angle. I might mention for one, attenuation along the wire might be involved, the influence of the ground on the system may be involved. But all in all, I consider this a substantially good check on the conception which has been previously discussed.

Mr. Darby: It has been called to my attention, if the Court please, that due to the fact that this subject matter is involved in some Patent Office proceedings, the witness has been referring, much to my surprise, to entries which do not appear on the photostatic copies that I have in my possession, but I am informed by my associate on his photostatic copies, those entries have been made. So from now on, I am going to hand the witness a clean photostatic copy of each page.

The Witness: I believe that the entire page of August 9, 1927, that I have here is in my handwriting. The entries thereon were made on the date in the upper left-hand corner, August 9, 1927.

I have the record here of August 10, 1928, in my handwriting, with the exception of a witnessed signature, which I see on the bottom. I will read:

"Methods of using tilted wires in combination, in order to illustrate the principles involved, a 3 lambda."—

which indicates wave length—"tilted wire is used as an element."

So far as I can see, this is much the same as the previously [fol. 522] discussed conception. This appears to be in general appearance a reproduction of a previous conception.

On the lower part of the page, I see arrangements which differ from that on the upper part of the page, only in that the element was added in an upper direction—I shall refer to the copy for anyone who wishes to see what I mean by that.

It is just merely another means—a means that was conceived at this time for employing tilted wires as elements.

The original was witnessed on 8/10/28 by C. R. Englund; Mr. Englund is one of my associates in my company.

I think it is true that, with the exception of the statement that I have last read into the record, and Mr. Englund's signature, all of the entries on this page of August 10, 1928, are in my handwriting. The entries were made on the date indicated opposite my signature, which is near the lower right hand part of the paper. It says, "Signed, E. Bruce"—August 10, 1928.

My attention is called to the fact that that last page that I referred to, prior to the one of August 10, 1928, was August 9, 1927. As to what I did in connection with this subject matter during that period of one year: As these different items have been conceived, there has been a vast amount of work in checking both theoretically and by experiments, variations alteration to the experiment, such as varying the length of the wire. Calculations were being made and theoretical plots have been made, and experimental checks of the plots have been attempted, and there is a vast amount of work which I have in my note book here which was done in the intervening period.

[fol. 523] The Court: These curves that have been considered now, they represent your best results, do they?

The Witness: I think in general—these are the conception of the first experimental results, they are not the best result.

The curve of July 26, 1928, is entirely in my handwriting. It was made on July 26, 1928, by me.

I think this is a plot of data obtained in a test on what I have termed an inverted V antenna, each element being four wave lengths long. The coordinate of the plots, for the abscissa, reads: "V vertical in degrees," and the angles are indicated: the ordinate reads, again, "in T. U. over half wave vertical." What is implied there is that we compare the output of the receiver connected to an inverted V antenna as described to the output of the same receiver when it was connected to a half wave vertical antenna.

The difference between T. U. has been plotted as the ordinate. In the center of the paper is a dotted line which says theoretical optimum angle.

Again, I would like to mention that I mean by theoretical optimum angle, the angle given by the predominating principle that governs the layout of these antennas.

Of course, as I have said before, there are other small factors, which I prefer to call correction factors, which

slightly alter the result, but in spite of these small correction factors, we show here experimental evidence that the check is reasonably good with that of the theoretical optimum angle as indicated.

From August, 1927, to the 1st of August, 1928, I personally devoted time to that subject, research along that [fol. 524] line. I can certainly say that the majority of my time for my company was employed during that period, in scientific research of tilted wire antennae.

Mr. Darby: I will offer in evidence at this time, the photostatic copy of the chart referred to by the witness.

(Marked Defendant's Exhibit LL in evidence.)

The next record I have is March 5, 1930. Reading on the top, this sheet says: "continued", evidently from a preceding sheet, "antenna schemes for horizontally polarized wires." Seven different schemes have been set down on paper in order that they may be compared, and I think only the last one is of interest.

Incidentally, I do not believe this is the earliest construction date of this, if I may refer to my notebook, perhaps I can dig that up. This is a witnessed paper of the conception, rather than the individual antenna involved.

Confining myself to the last sketch on this paper indicated as No. 7, it says: "Horizontal double Vee." There is indicated a plan view of layout using four elements as has been taught by the principles which I have discussed. There are certain notations on here, certain wave directions assumed, I see, on the right. I see in the center, the general diamond formation, where it says, "L minus lambda over 2." That is intended to indicate that the projection of the wire on the wave direction is a half wave length less than the length of the wire. As this is a right triangle and two sides have been determined, the angle is correspondingly determined by anyone who wishes.
[fol. 525] The item is signed with my signature with the date of March 5, 1930, and is witnessed, I see the signature of H. T. Friis, March 5, 1930.

Q. 98. Now, I notice that there are nearly two years intervening between the date of the last entry that you have referred to and the record that you have last referred to. During that period, did you do any work in research along the line of these antennæ that you have testified about?

A. That is very true.

In research work of this nature it was hoped that we would not be so narrow as to confine our attentions to one particular type, excluding all other types, but to carry the development along of a number of types simultaneously in order, when they were finally developed, that we may compare those types and select.

During this interval of time there were quite a number of types of antennas which were conceived, calculated theoretically and experimented with, all of the progress going along as a unit, with the intention of comparing the types when completed. Of this work during those two years in research on antennas of this character, all has either been done by myself or under my direct supervision. As to what proportion of my time, during this two-year interval, was devoted to research on antennas: If I remember correctly, I was sent to England on other work for a period of time and other than that period, I can answer your question by saying the majority of my time was on this work. I am referring to a second trip to England—speaking from memory, I would say I was in England on this second trip approximately four months. To be absolutely certain of the year, I would have to look up that date. It may possibly be 1929, I am not sure.

[fol. 526] Q. 105. Now, referring momentarily to the curve which is in evidence as Defendant's Exhibit JJ, will you state what enables you to fix the time, as you have fixed it in answer to a previous question, or at least the range of time within which, to the best of your recollection, you discussed this with Mr. Couzens of the Patent Department of your company?

A. I disclosed the exhibit in question to Mr. Couzens on a visit that he made to Cliffwood, New Jersey, where I was working at that time.

At a later date, or first I should say it is my understanding, or I am fairly certain that I saw Mr. Couzens in his own handwriting, sketch a similar sketch to the one that we have discussed, and I signed the paper. He took that away with him.

After a period I realized the importance that that particular paper might be and I spoke to Mr. Friis about it. He was going to New York and I requested him to speak to Mr. Couzens about the whereabouts of this paper. As a result of that visit, I received a letter from Mr. Couzens which you

have just handed me. I recognize Mr. Couzens' handwriting. That is Mr. Couzens' handwriting because I have the original letter of which this is a photostat. This letter from Mr. Couzens was sent by mail and I received it.

Our company, to my knowledge, has erected commercial antennas embodying the results of my research work as I have outlined it. As to the stations: Rather than speaking from hearsay, I will only mention those that I have actually looked at myself. I have seen one such antenna which was erected at the ship to shore station of the American Tele- [fol. 527] phone & Telegraph Company at Forked River, New Jersey. I have seen that.

Another antenna of this general type (which I have seen) was erected at Netcong, New Jersey. I believe that antenna was intended for communication with Bermuda. At least I have a distinct recollection of those two stations. I understand that there are others.

You ask me what a rhombic antenna is: There has been evolution of names for this type of antenna. I first called that general form a double V, which admittedly is a crude term. I thought that the expression "diamond shape" was a little more descriptive in that it indicated that there was an opposite relation between the two V's. There again, it was a crude term.

Finally, looking up the technical term for that shape, a diamond shape, why, rhombic fitted the case, and from that time on this antenna has been known as a rhombic antenna.

The commercial stations that I referred to as having seen, or known of their existence of my own knowledge, these were all rhombic type.

I have received scientific honors for the work which I have done, especially citing my work on this antenna research. To be strictly accurate, I would like to see the citations in each case that accompanied such honors. I think they were a little broader than covering this subject. However, the subject was mentioned. As I recall, in 1932, the Institute of Radio Engineers awarded me the Liebman Memorial Prize, which I believe is given as their selection of the papers that have been presented to the Institute during the year.

[fol. 528] In 1935, I received the Wetherall Medal of the Franklin Institute, which again had a broad citation, but

in the citation was mentioned the work concerning rhombic antennas.

I referred to a paper in connection with the Liebman Memorial Prize of the I. R. E. I prepared a paper and submitted it to the Institute, and they suggested that it be given personally at their Sixth Annual Convention on July 6, 1931, at Chicago.

Circumstances prevented me from attending that meeting, but Mr. A. C. Beck, who has assisted me in a great deal of this work, gave the paper in my stead. The convention may have lasted for several days, but it was within the vicinity of that date. The paper was subsequently published in the Proceedings of the I. R. E. I have here the Proceedings of the I. R. E. of August, 1931, in which I see the paper in question.

I mentioned that Mr. A. C. Beck assisted me; Mr. L. R. Lowry similarly assisted me during that period in 1928 in my research work.

Mr. Darby: I offer in evidence as one exhibit the photostatic copies of the pages under dates of May 13, 1926, May 14, 1926, the second page of May 14, 1926, July 19 to 21, 1927, August 2, 1927, August 9, 1927, August 10, 1928, March 5, 1930, and the Bruce letter of July 25, 1927, that is, the Couzens letter to Bruce. If there is any question about this last proof, Mr. Couzens will be my next witness.

(Marked Defendant's Exhibit MM in evidence.)

[fol. 529] Cross-examination.

By Mr. Brown:

The Witness: I have been specializing as a research engineer for the American Telephone & Telegraph Company on short-wave radio communication since about 1924. Also I have had working with me and under my supervision a number of similarly trained radio engineers. Of course I know a lot more about this subject now than I did say in 1926, 1927 and 1928; there is no question about that.

X Q. 131. And I assume that in going over your notebook, and so forth, and telling us what they represent, that it is only fair to say that you are interpreting them in the light of what you now know, is that right?

A. I am not certain that that is right; I have tried to interpret them in the knowledge of the times.

X Q. 132. Well, of course, you recall and I recall that a number of times you stepped off the page of your notebook and told us a number of things outside of that, and I assume that you were telling us what you now know or think you know to be a fact.

The Court: Did you go outside of your notes at all, and if you did, then——

The Witness: He is referring to the particular diagrams, and in my attempt to interpret them in terms of my knowledge at the time they were made—I thing in a number of cases that if you had asked me to interpret those in terms of personal knowledge, I may add features—. I have attempted, to the best of my ability, to answer as of the date of my notes.

[fol. 530] I approached this study by examining the prior art, reading the prior art; one of the things in that that interested me was the so-called wave antenna. That the wave antenna is one that depends upon the tilt of the wave which you might say traverses the wire, is what was taught by the reading material that I had at hand.

In reading this material, the wave antenna, as I understood it, was extended substantially horizontal. There exists a wave tilt and you have to accept as a physical fact the angle between that epuiphase wave front in the wire in question, and in my first experiment, which I described to the best of my ability, I had precisely that feature in mind.

The first experiment that I described, as dated May 13, 1926, consisted of one wire substantially horizontal.

That wire was intended to work in the manner in which wave antennas worked, that is, it was approached by a wave with a tilt. The thing that I hoped to achieve by this test was so to arrange a second wire in relation to that first wire so that the useful component of the electric vector of that wave front would induce, in the second wire, a similar magnitude to that of the first wire, but so phased that the result would be cumulative at the receiver, and in my opinion that was achieved, to some extent, at any rate, by this initial experiment.

I did not know the wave tilt, therefore I have variables of the divergences of the wire involved here, always keep-

ing the horizontal wire fixed, as teachings of wave antenna practice had recommended, and adjusting the second wire in relation to the first so that the induced voltages cor-[fol. 531] respond with proper phase relations to be cumulative at the receiver. I was using a horizontal wire as the old wave antenna; I tried to explain that the wire was substantially horizontal, there existed the wave tilt from the surface wave which arrived at the distant oscillator. Incidentally, I have tested that; I know that there is a wave tilt there. I can prove it from experiments. In relation to the wire, I tried to put a second similar wire so the voltages appearing in the wire would correspond to the voltage in the first wire, but so connected in the receiver that the result is cumulative. Now what I am trying to say here is that I wanted these two wires to perform in the same manner. This was an experiment which led to the discovery that there was an angle between those wires which was beneficial. My first conception was based on just the attempt to get the same magnitude in the two wires. My later conception of how the thing worked, taught me that I was not performing it in the most desirable manner; I was performing it in a manner which was helpful, but there were other manners which were more so. And this first experiment does not involve necessarily the critical angles which are described on the exhibit of September 28, 1926.

I went on with further experiment to determine just what would be the optimum tilt of this wire which I was going to incline upward from the earth. What I arrived at as a general proposition was that the length of the wire which was inclined to the earth's surface should be a half wave length longer than its projection upon the earth's surface, in reference to the wave direction assumed. In other words, what I arrived at was, assuming six inches of [fol. 532] this rule to be a half wave length, that the proper rule for determining the angularity of my wire was that where the wire was three half wave lengths, that a vertical line dropped from its end would determine the length of the line, which was only two half wave lengths in the horizontal. I was assuming that the wave arrived in a horizontal direction; in this case, there isn't any difference, but I do not want any misunderstanding when we get to other cases.

X Q. 149. Well, as far as the notes you have produced are concerned, they have all assumed that the wave arrived in the horizontal direction, and therefore this line which determines the projection, that is the projection of the tilted wire, would be on the horizontal plane, wouldn't it?

A. In relation to this work, the construction was under an ideal basis——

X Q. 151. Isn't what I said right, about the notes you have produced, isn't that the way all of the notes you have produced read, and isn't that the figure you show in each case, that you assume that the wave is arriving in the true horizontal direction, and your wires are tilted up from that horizontal plane, and their length of angle is determined by the rule or law that the projection of that wire shown on the horizontal plane would be a half wave length less than the length of the wire itself?

A. Where the plane is sufficiently good to represent a mirror.

X Q. 152. I am talking about what your notes show, Mr. Bruce.

A. Yes, that is right, that the conception of September 1928 follows your description.

Everything I have produced is exactly that way, that law that I have stated, that the angle of my wire to the [fol. 533] direction of the arriving wave that I have assumed is determined in length by the rule that the length of my wire shall be a half wave length longer than the projection of that wire on the line of the signal received. I would like to point out in that connection, I have tried to say, that that was the dominating rule. Like all things in nature, there are slight things which detract from the dominating rule, and have slight variations, and I thoroughly appreciated that and I believe I can substantiate that claim.

It is correct that every antenna that is referred to in my notes up until some time in 1930, was either a single wire tilted up at an angle to the horizontal plane, or else a V arrangement in a vertical plane with the open end of the V down against the ground or towards the ground, and with the apex of the V at the top. In every case, each of these antennas was fed, in the case of a transmitting antenna, or the receiver was located, if it was a receiving antenna, at one corner or one end of the V.

X Q. 157. In no case, was the V divided at the apex and the two sides separately connected to the receiver or transmitter?

A. I wish you would qualify that last statement to include the first experiment which I performed. I am referring to having two elements at divergence with the apparatus connected in between, which is the first experiments performed.

X Q. 159. With the exception of your experiment of May 13th and 14th, what I have said is correct, I believe, isn't it?

A. Correct for the particular pages discussed.

At the bottom of that figure on my notebook page of August 10, 1928, I showed the V arranged differently from [fol. 534] the showing of any of my other notebook entries in that it was, you might say, turned on its side with one of the corners at the bottom, and with the apex pointing in horizontal direction. After this conception, I had Mr. Beck and Lowry test this particular arrangement. If my recollection is correct, for the length indicated on this figure of 3 wave lengths, it was not a very good antenna, but they found that there were other lengths in which the antenna was not at fault. I don't believe that the particular thing shown on my notebook page would give any worth while results as a receiving antenna.

May I say that in all the work—I don't know how this page was selected for evidence—but I have mistakes as well as useful things that occur. Even to a research engineer like myself, a good many things that I put down on paper may not work out when I put them to practical use.

I did some reading and study of the prior art, before I approached this subject. I was familiar with a certain article written by Levin and Young in which there are certain formulas quoted. I have never seen an article written by a man named Abraham directly. I had this Levin and Young article in mind in working out these antennas. It was published at a vital time in my work—I was very much impressed with its importance in connection with my work, and I have placed it in my daily notebook here for reference.

I made a note at that time, and yet, I went on with my research and experimentation in trying out these straight wire antennas for a number of years afterward, before I arrived at my rhombic antenna.

[fol. 535] I said that I knew of two rhombic antennas that had been erected by the American Telephone and Telegraph Company. I do not know when they were erected. I would have to refresh my memory, if I am to be held to a certain date as to when I saw them. They were erected pursuant to my research and development of the rhombic antenna. I presume they certainly would have been after my sketch which was produced here as some time in 1930.

In my tests of May 13th and 14th, particularly that shown on my notebook of May 14th, where I said I made some directivity tests (1926). I had there an antenna comprising a horizontal wire, and a tilted wire running from the receiver. The transmitter was the element that was moved; I moved that around my antenna. It is substantially correct that all of my measurements for directivity were taken in the horizontal plane.

X Q. 184. And there is nothing on those two notebook pages of May 13th and 14th to indicate any determination of directivity in the plane of the two wires of the antenna, is there?

A. Merely that it is implied by the fact that——

X Q. 185. Will you answer my question first, and then you can say anything else you want?

A. I am not certain that that is true.

(The Reporter repeated the question.)

X Q. (Continuing.) I say, other than in the horizontal plane?

A. There is no direct tests other than the possibility—you may not be satisfied with that—the fact that the divergence of the wires was varied. But when you had read the early readings which I had, which indicate that gains are achieved [fol. 536] partially through increases in the directivity of the antenna, I felt that in the vertical plane, the same as I had been taught by wave antenna literature that I had read, that there is certainly a directivity expressed there, and I was familiar with that at the time. And I was attempting to correlate to elements here and got a very end result, and I am certain that I felt that there was something there, but I was unable to measure it on this particular date. I certainly did not put anything down on those notebook pages about it.

Then over on the notebook page of July 19, 19?7, I was still experimenting with this single-tilted wire runni. up to the top of the pole. I was still experimenting there with the question of the best length of wire and the best angle, because every time I changed the length I changed the angle to the horizontal. I was striving to find the optimum for each length.

As to what I put down as being the thing I determined at that time as being important: I see by the column labeled T. U. that a greater output was achieved for the four wave length case, than any of the shorter lengths. I do not see that the angle at which that four wave lengths was used is written on this page. However, the angle is determined from the dimensions given or can be determined. I made a column for the angle, but did not fill it in; that phi up there in next to the last column is intended to indicate that angle. Phi has been a symbol for me in this work as the angle between the pole and the wire. It would not make any difference if I called that angle theta. [fol. 537] In the sketch in the middle of my notes of July 19, 1927, I have indicated there the distance D as being from the foot of the pole to the receiver. Then, at different times, I indicate wires of a number of different wave lengths. I think in that particular case, lengths were added to the existing wire, which is equivalent to a longer wire. It is not correct that each time my wire would extend up to the top of the pole. There was a fixed pulley at the top of the pole, and I tried to explain in the testimony that there was a rope that ran over that pulley, and as we varied the length of the wire and also the position of the receiver at the base of the pole, we always tightened up on that rope so that there was no slack. That, of course, for a long wire would take the receiver, if it is remote from the transmitter, I mean the remote side of the pole, that would mean the whole system is very slightly moved away from the transmitter. But since the transmitter is at a distance and that variation in distance is only small, why, it is not vital in my opinion in this experiment.

The distance D as shown on my sketch does not represent correctly the projection of the wire on the ground.

X Q. 202. And you mean D meant the projection and not the distance to the bottom of the pole, or did it mean the distance to the bottom of the pole?

A. I gather from the diagram here that the arrows point to the foot of the poles, so I am certain that that is the way it was measured for this experiment. The wire would not have made a projection equivalent to distance D in each case.

The note I made on that experiment simply was that the experiment showed that it was apparently important to [fol. 538] avoid sagging in the tilted wire. Just to help you, may I say, though, that that distance that you are interested in, can, I believe, be determined by such dimensions as are given here. Let me see: The height of the pole would have to be known, in order to do that. This happened to be a steel tower which is still in existence down at the location D on Vesey Street. That doesn't appear in my notebook, so we apparently couldn't do it without knowing the height of the tower.

In the beginning of my testimony yesterday afternoon, I said that the cost of the antenna was one of the considerations.

I was working on these experiments from May of 1926 on up through 1930, on these various forms of straight wire antennas, and some time after that, the Telephone Company built two of my rhombic antennas. I don't know the comparative cost of my rhombic antennas and antennas that were being built by the Telephone Company between 1926 and up to the time that it built my rhombic antenna.

X Q. 212. Do you know whether there is a very great difference in the cost—if you don't know quantitatively, do you know in a way that you can give us a general comparison of cost of erecting one of your rhombic antennas as compared to antennas that were being erected by the Telephone Company during the period of 1926 to 1930?

A. The only knowledge that I have on the subjects of costs are these:

Much of my efforts, which has not been brought out in this evidence, is to have antenna that is not restricted to a single wave length, but can be used on a number of wave [fol. 539] lengths and that to me seemed to be considerable economy.

I have expressed such things in publications where at one time we were required to build a number of structures, and following my teachings, they only had to build one structure, and it is obvious, just comparing the amount

of material involved, that the rhombic antenna would be cheaper than a number of these other structures; I believe very much cheaper.

I came here voluntarily.

Mr. Brown: Mr. Darby, do you admit it to be a fact that Mr. Bruce has an application for a patent, into which his attorneys have copied claims out of one of the Lindenblad patents here in suit?

Mr. Darby: I admit that to be a fact, that there is an interference pending between an application of Mr. Bruce and the second Lindenblad patent. That is a fact, but I do not admit that it is relevant to this controversy.

Mr. Brown: And you admit also that none of the claims involved in suit here are involved in that interference?

Mr. Darby: If you state that as a fact, I will admit it, but I do not see that it is relevant in this matter.

The Witness: Referring to the antenna, which I called a rhombic antenna, that is shown on my notebook page of March 5, 1930, at the bottom of the page, as drawn, it is substantially unidirectional, because of the attempt of terminating the far end. As to how I make that antenna into a [fol. 540] unidirectional as distinguished from a bidirectional antenna, as shown on this sketch: There is indicated on the far end resistance which is labeled Z sub zero sine pi. Removing that resistance, it alters the impedance somewhat of the antenna and requires somewhat rematching of impedances at the opposite ends, that being assumed, I suppose. After rematching, in examining the front to back, or I should say tendency towards unidirectional characteristic, one would find that there was a tendency towards unidirectional characteristic due primarily to the attenuation along the wires involved, but on inserting this device at the end of the wire and properly adjusting the device, a very much better tendency towards unidirectional antenna can be achieved. It is substantially true that that adjusting device which I have there at the end of my antenna, which is toward the direction from which the waves come, absorbs the waves that would be set up on that antenna in one direction, so as to produce a traveling wave antenna in fact.

X Q. 225. I will ask him to just tell us what effect this resistance element that you have marked ZO, isn't it, in

your sketch of March 5, 1930, has in the matter of absorption of power that is received by that antenna?

A. I think this question has been answered in publications referred to to some extent, but I will elaborate on it. If the direction of waves is in the direction as indicated as we go along the wires, there is an accumulative effect which builds up in the receiver. Should that receiver be so matched into your system so that there is no reflection, nothing travels, naturally, to the far end via that reflection.

[fol. 541] Now, we can examine in the opposite direction. If one goes along the wire and finds out from this wave what voltage appears across that at the far end, they will find, even though that impedance is not there, that the voltage between those two points approaches zero for a case receiver.

As a further explanation of what I have said, suppose we put the wave direction on the opposite side towards the receiver. Let us assume that the receiver and this far end termination are substantially the same elements, which would be pretty close to the actual fact. I have explained when the wave comes from the right there is a voltage accumulation across the terminal points from the source of that wave, and that practically no voltage appears across the circuit element that is nearest to the direction of that wave.

Now, just interchanging the direction of the wave just merely reverses that behavior. What we formerly called the receiver that could accumulate effects now becomes the far end termination which we previously had said had no appreciable voltage. Therefore, the receiver has no appreciable voltage, and the energy which travels to the far end, which now acts like the receiver end previously, absorbs the energy from that direction.

X Q. 229. Isn't it a fact that at one end of this rhombic antenna you have a receiver, and at the other end you have an absorption resistance circuit, and that you get unidirectivity by letting the waves or energy, whatever you want to call them, from one direction go through to the receiver, and in the other direction let them be absorbed by this resistance element?

A. When the wave is in the improper direction, 180 de-[fol. 542] grees improper, why, the energy of the wave is absorbed at the far end termination.

I achieved unidirectivity with this rhombic antenna by absorbing the waves at one end in an element which does not use those waves in any way for producing signalling effects.

X Q. 232. Now, on the page dated March 5, 1930, at the top, you have still a different kind of antenna shown, haven't you?

A. I wish you would not discuss that. It does show that at that time I was working with something else besides this rhombic antenna.

This rhombic antenna that I have told you about is, in the embodiment under discussion, composed of four sides arranged substantially in a diamond shape in which I position my receiver or transmitter, as the case may be, in one corner, and then this absorbing resistance that I talked about at the other end, in case I want it to be unidirectional, and then the wires between are serially connected together, that is, one wire running around there. The V element that is used in my rhombic antenna is this wire which runs from one end to the other and with the two wires connected together at that apex; that is the V which I referred to when I called it an inverted V.

X Q. 238. When you speak of the V in your notes you are talking about this inverted V that is set up over the ground, is that right?

A. A V to me is a description of a structure—any structure that is a V.

X Q. 239. I am asking you what you talked about on your direct examination when you spoke of V's. Now, as I recall, the only V's that you talked about were where you put up two tilted wires in a vertical plane, a practical V turned upside down?

[fol. 543] A. With the exception of when you get into the rhombic discussion.

X Q. 240. Well, your rhombic antenna is made up of putting two of these V's you might say, point to point, isn't it?

A. I would say with the proper apparatus.

X Q. 24.. I mean as shown on your notebook page, that is true?

A. Point to point, or diamond formation, with the apparatus at the terminals.

As a matter of fact, these V's that I talked about, these inverted V's as shown in my notebooks before 1930, were erected in a vertical plane.

X Q. 243. What would be the direction of transmission or reception in so far as they had directivity, with respect, you might say, to the geometric shape of the V? Would it be along the bisector of the angle of the V or at right angles to the bisector of the angle of the V?

A. In order to accurately answer that question we have a distance which I wish you would name. For instance, the surface wave which I have mentioned frequently dies out at great distances and is inappreciable, and we have a space wave.

In every instance, my notebooks—where they have any indication of directivity—have an arrow pointing indicating a horizontal direction with respect to these vertical V's; the conditions are assumed in the ground, I mean perfect reflecting ground was implied there, to suit those conditions.

Under those conditions, the directivity of the V's that I showed in my notebook was at right angles to the bisector of the angle between the two wires that went to make up my inverted V.

I have spoken a number of times of perfect ground. Of course, you never have perfect ground in practical antenna work.

[fol. 544] Although you would not have the actual horizontal directivity of transmission or reception that is indicated on these notebook pages, you would have them very close to that in the case of vertically polarized waves.

X Q. 250. What horizontal polarized waves?

A. I don't believe any horizontal directivity has been given——

X Q. 251. If I understand rightly, these antennas you are talking about would not receive horizontally polarized waves, is that right?

A. In the latter part of the testimony horizontal antennas were discussed, if I remember rightly.

X Q. 252. That was the rhomboid antenna, and in the 1930 notes?

A. Yes.

X Q. 253. If I understand you correctly, then, everything that you show before that was limited in its ability to receive to vertically polarized waves?

A. As indicated on the sketches; however, I would like to say that any technician working on this subject has the job of lining up the plane of this arrangement with whatever the plane of the electric vector is. The assumption of perfect ground is a helpful means of allowing him to get his ideas. The elementary theory on such subjects usually takes one off in space and tells you to line up the component of the wire involved so that it is parallel to the electric vector.

X Q. 256. Isn't it a fact that the arrangements actually shown on your notebook pages, prior to 1930, were adapted only to receive vertically polarized waves?

A. Well, in the evidence before us, I believe that is all that was discussed, other than the rhombus antenna.

[fol. 545] I referred to receiving from the Franklin Institute the Wetherall Medal; as a matter of fact, it was the Longstreth Medal.

The unit that I used in my notes of August 9, 1927, where I refer to deflection as an indication of a true signal, to show the improved signal, that is not the same unit that I use, for example, in my notes of May 13, 1926. The units employed here are deflections in microamps, which are roughly proportional to the square of the input voltage.

Previously I discussed two other types of units, one was the ratio of voltage which was on the earlier testimony, and the later testimony was in T. U. units, which today we call D. B. I was not talking about the same measurements in those two.

I spoke about making a couple of trips to England; they were on business in connection with short wave antenna development.

X Q. 264. Now, will you refer, please, to your notebook page of March 5, 1930, and I note that that is marked, at the top apparently as page 2. I will ask you whether there is anything on page 1 referring to horizontal rhombic antennas?

A. No, there is nothing relating to horizontal rhombic antennas on page 1.

X Q. 266. Now, still referring to your page of March 5, 1930, and to the rhombic antenna which is shown at the bottom of that page, and recalling your testimony this morning to the effect that these antennas were equivalent whether used as receivers or transmitters, will you tell us whether

you know as a fact, if the receiver is replaced by a transmitter in that arrangement, what percentage of the total input power would be wasted in resistance C0 at the end of the antenna?

[fol. 546] A. I understand that the power that went into that resistance would be absorbed and not radiated, is that right?

A. For the wave in what I call the back direction.

X Q. 268. Then can you tell me approximately what percentage would be absorbed—power input?

A. Well, it would be a very large proportion. It would be 40 or 50 per cent or possibly more. As to the radiating efficiency of that particular antenna, when used as a transmitter: If we are willing to acknowledge that the removal of that resistance changes the impedance of the system, and we are permitted to rematch the apparatus, then the forms are nearly comparable, but in removing the resistance that sort of effect does take place, but provided we make such a readjustment—

X Q. 275. I am merely asking you about the antenna as it is, not as you might perhaps rearrange it. You said, this morning, something about a reciprocity rule that these antennas were the same whether used as a transmitter or receiver. I am asking you about a transmitter where it is changed to a receiver. Tell me what would be the radiating efficiency of that antenna, leaving it just as it is.

A. That is quite a different question from the previous one you asked. I will answer the first question first. The effect of the far end termination, substantially, if I may ignore any slight readjustments in the impedances of the terminals, is substantially this: that with the resistance there, we may get a certain field strength at a distant receiver. There is power absorbed in the resistance from the transmitter. Now, if we take that resistance out substantially, the field strength in the distant receiver, at the distant receiving [fol. 547] point is unchanged. However, the power which previously was absorbed is now sent out in both directions. Will you repeat the other question?

(X Q. 275 repeated by the reporter.)

A. To give a definite answer to the effect, leaving the transmitter just as it is, gives you a complicated situation. There are not enough precise values given to give a precise answer. I am referring to the mode of impedance mis-

matching that is effected. I assume you meant changing this system, removing the resistance at the far end, what happens?

X Q. 279. You have answered that question. I thought you answered that by saying then you would get radiations in both directions?

A. Yes, but probably I am talking about a minor detail whereas you are after the major detail.

X Q. 280. Can you or can you not tell me what is the effect, for the purpose of sending useful signal, of simply substituting a transmitter for the receiver in the antenna shown at the bottom of your notes of March 30th?

A. I will include in that a distant cooperating station. According to the theorem of reciprocity at the receiving station, the output of the receiver will be the same regardless of an interchange, regardless of the character of antenna connection at the two terminals. My reason for stating such is I believe the reciprocity law is valid where the circuit elements are linear. I mean by "linear" that if you double the voltage in the system, the current doubles. That is the definition of a linear system. If that condition holds, and I have no reason to expect a departure from that, in fact, experi- [fol. 548] ments made and observations made very closely show that to be true; then I think there is little difference in exchanging a transmitter and receiver, providing the transmitter's power is unchanged.

X Q. 282. Let us leave out the other receiver at the other end, and let us talk about strength of signals transmitted to a certain point that is coming out of these antennae. Now, will you tell me what is the proportion of power you can get in radiation in the form of a useful signal from that antenna with the resistance and without the resistance, and having a transmitter in place of the receiver.

A. If the circuit element is a transmitter, the forward radiation will be unchanged substantially whether that circuit element is in there or out. The function of that circuit element is this: When in there it absorbs the power which normally would be radiated backward if it were not present.

X Q. 284. Did you answer—just answer yes or no—did you answer as to the radiating efficiency of that antenna with that resistance in? If you did, I won't ask you to repeat it.

A. You want a yes or no answer to that, do you?

X Q. 285. You don't know the answer to that?

A. No, I don't know the answer to that.

Referring to my notes of July 19th and 21st, 1927, the second column there, the last entry, I made an arithmetical mistake in recording that as 2.1; that should be 3.1; it was just simply an error.

Referring to my notes of May 14, 1926, at the bottom I have a heading, "Top view directional characteristics". I did not make the same tests using the comparison loop for the receiving antenna.

[fol. 549] Referring to my notes of September 28, 1926, August 2, 1927, and August 10, 1928, and March 5, 1930; those are all theoretical.

Referring to my curve of July 26th, Exhibit LL, the inverted V on which I made the experiments upon which this curve is based of the same form (but differing in dimensions) as that shown on the top of my notes of August 10, 1928.

Referring to my notebook page of July 19th and 21st of 1927, there is nothing stated in so many words on that page to indicate that the measurements recorded are select measurements representing the best tilts of the various wire lengths used; however, it is my belief that these are optimum divisions.

The article entitled "Receiving Antennas", published in the Short Wave Transatlantic Radio of the Bell Telephone Magazine, commencing at page 42 of a pamphlet which has been put in evidence here as Plaintiff's Exhibit 22, is one that was written and submitted to me for approval. The actual composition of the paragraphs is not mine. It is published under my name.

X Q. 302. And do you accept responsibility for it or not?

A. I would like to read it closely before answering the question.

That article was published and put out over my name, as purporting to be the author, and was published in the Bell Telephone Magazine in July, 1928.

I wrote the article that was published in the Proceedings of the Institute of Radio Engineers for August of 1931, entitled "Development in Short Wave Directive Antennas".

Mr. Darby: I offer the article just referred to by opposing counsel in evidence.

[fol. 550] (Marked Defendant's Exhibit NN in evidence.)

By Mr. Brown:

X Q. 306. Mr. Bruce, I hand you a copy of British patent No. 392,201, and I ask you if that is the patent taken out by you or on application by you on your rhombic antenna?

A. By reading the first paragraph of the patent, that refers to me. I have never seen this before, and I would have to read it to answer your question.

X Q. 308. Well, take a good look at it and give us the best answer you can. Don't you know as a matter of fact whether that is a patent that was taken out on your rhombic antenna?

A. By examining the figure it looks to be the case. I undoubtedly have approved the application for that patent.

Mr. Brown: I ask that that be marked for identification.

(Marked Plaintiff's Exhibit 41 for identification.)

The Witness: United States patent No. 1,899,410, issued upon an application filed by me describing certain of the developments that I have described in my testimony this morning, with the exception of Fig. 16, which was added by amendment some time in 1931, in December. So far as I know, that correctly describes the invention that is purported to be set forth in that patent.

Mr. Brown: Now Mr. Darby, will you require us to put in a certified copy of the file to show that Fig. 16 and the text [fol. 551] describing it, was added by amendment in December, 1931?

Mr. Darby: I am perfectly willing to accept your statement of fact as to that, subject to any correction that the facts may necessitate.

Mr. Brown: Under Mr. Darby's consent, I offer during his proof the British patent as Plaintiff's Exhibit 41, previously having been marked for identification.

Mr. Darby: I object to it because of its lack of relevancy.

The Court: I will take it, subject to the right to him to move to strike out when you file your briefs.

Mr. Darby: I note an exception to the Court's ruling.

(Plaintiff's Exhibit 41 marked in evidence.)

Mr. Brown: Then I offer as Plaintiff's Exhibit 42 United States Patent 1,899,410, that has been referred to by the witness.

handwriting. I am not certain about the numbers above that. Some of them may have been in my handwriting. Two of us did this together. The other man was Mr. Lowry.

We were at this time doing experiments under Mr. Bruce's direction on antennas of his design.

Irrespective of whether I made the notes, I recall what was done; I assisted in the test.

We put up a half wave vertical wire, according to these notes, and the coupling to the set was two and a half turns above ground on a six-turn coil. We then wrote down that the attenuator setting for 80 microamperes change was 23TU and that the attenuator setting recorded here for [fol. 560] 30-30 microamperes was 89TU. That is a measurement of the gain of the receiver when the input was 30 microamperes and the output 30 microamperes.

We then subtracted those two to determine the amount of gain that was necessary in this receiver with this particular antenna connected and with the oscillator that we had placed out to measure these antennas. Having made that record we put up a one wave length wire and tilted it toward the oscillator. The coupling changed to one and one-half turns above ground on a six-turn coil. And the attenuation of the receiver for an 80-microampere deflection was 26 and the second deflection, the set gain, was 89. The difference here was 63, minus 63.

We then changed this antenna to a two wave length wire which was folded in the middle. We added another section to the top of this first one, which was one wave length long, as indicated by the symbol similar to a V turned on its side, after two lambda. The apex of the V was pointed toward the oscillator. The coupling remained one and one-half turns above ground on a six-turn coil. We have here a notation that the first top of the antenna was at the top of the pole, as high as we could hoist it, and the attenuation for an 80 microamp deflection was 23½. The second attenuation for 30-30 microamp deflection was 88, and the difference indicated as 64½.

We then lowered this same wire down one meter from the top of the pole. The first attenuation for an 80 microamp change was 23¼, and the second attenuation for a 30.30 microamp deflection was 88, which gave us a difference of attenuation of 64¾.

[fol. 561] The next notation here is not very plain. I do not know what this "meters down" indicates from this photostat. I assume it is a two, but I don't know that for sure. For that test alpha one for 80 microamp deflection was 22 and alpha 2 for 30-30 microamp deflection was 88, and the difference in attenuation was 66.

We continued on page 2, for four meters down, and five meters down, and six meters down, in the same manner.

Q. 17. Will you go on to the next stage and point out in what respect these series of experiments differ from the preceding one?

A. Do you mean page 2, under date of 8/16/28?

Page 3 under date of 8/16/28 starts off, 4 lambda. At the top of the page, the date 8/16/28 is in my handwriting. This is apparently continued from some other test of that date from the notation at the top of the page, and it starts with 4 lambda and then there is an indication of a diamond-shaped antenna.

We went on from the test that I described before and completed the diamond-shaped antenna.

4 lambda means that each element of this diamond was one wave length long. The coupling of this antenna to the set is now one turn above the ground on a six-turn coil.

One button pressed reverse to the receiver. There were buttons on it to determine the gain that was used.

The first notation is, with this at the top of the pole, of an alpha one with 80 microamp change is 22¾. Alpha 2 for a 30-30 microamp deflection is 87.5, and the difference is 64¾.

We then lowered it one meter and it was one meter down from the top of the pole and the attenuation for 80 micro- [fol. 562] amp deflection was 21, and alpha 2 for 30-30 microamp deflection was 87.5, and the difference was 66.5. We lowered it to 2 meters down and alpha 1 for 80 microamp deflection was 19.5 and alpha 2 for 30-30 microamp deflection was 87.5, and the difference was 68.0.

With this same antenna three meters down, alpha 1 for 80 microamp deflection was 18.0, and alpha 2 for 30-30 microamp deflection was 87.5, and the difference was 69.5.

We then lowered it to 4 meters down, and alpha 1 for 80

microamp deflection was 16.5, and alpha 2 for 30-30 microamp deflection was 87.5, and the difference was 71.0.

Then at 5 meters down, alpha 1 for 80 microamp deflection was 13.5, and alpha 2 for 30-30 microamp deflection was 87.5, and the difference was 74.0.

On page 4, under date of 8/16/28, we seem to have gone with the same antenna, from the heading, four wave length —an antenna with a diamond figuration sketched here, to eight meters down and alpha 1 for 80 microamp deflection is 17.0, and alpha 2 for 30-30 microamp deflection is 87.5, and the difference is 70.5.

These records were made under the date at the top of this page, 8/16/28.

Turning to the next page that is undated, but headed "Set No. 7", I believe the first of this is in my handwriting, lambda over 2, case 1, vertical filter switch closed, one button pressed, and the coupling was two and a half turns above ground on a six-turn coil, and for an 80 microampere deflection, alpha 1 was 22, and alpha 2 for a 29-29 microampere deflection was 87.5, and the difference was 65.5TU. I am not sure that that 65.5 is my handwriting now.

[fol. 563] I don't believe I worked with anyone else except Mr. Lowry and Mr. Bruce at this period.

Referring to the notes on this last page: The first thing we had was a wire one wave length long and we tilted it towards the oscillator and coupled it into matched impedances again and measured the output from that wire. We then took the same antenna and tilted it away from the oscillator and measured its response. We then built a two-section antenna, two wave lengths long, each wire one wave length long, similar to the preceding case, except that the apex of the V is now pointed away from the oscillator. This would indicate that we started to test this in the same manner because we have a column height from the top of the pole in meters, but there is an entry here only for zero.

I believe these photostats of pages numbered 24 to 33 inclusive are photostats of records kept by me during the period concerning which I have testified.

I continued experiments with various forms of tilted wire antennas under Mr. Bruce's direction during that period, and it was some time later that we moved the laboratory from Cliffwood to Homedale. When we moved and set up new structures, Mr. Bruce assigned me the job of build-

ing certain antenna structures on the new location, and this sheet, No. 25, which starts "Two lambda at 32.2", appears to be in Bruce's handwriting. It was a slip which he gave to me to locate the poles that we were to have set on this new location.

It is labeled "Long Farm", and at the top, upside down, it is labeled, "The edge of the wood", and a pointer 200 or [fol. 564] more, I presume, is feet, and these four poles that are marked 260 feet apart in one dimension, and 380 feet apart in the other dimension, seventy foot poles, were to be erected as soon as possible to build a horizontal rhombic antenna. It was not known by that name then. It is a horizontal V antenna, which was a continuation of these experiments.

There were some other hundred foot poles located a little farther on that were used for building other combinations of tilted wires to compare with this antenna, and from this sheet those poles were set——

The arrow "England" on the right hand side of the page meant that in surveying the location for those poles we were to take that as the great circle path from our station to Rugby, England, which was the transmitting station of the British Post Office that we used for testing these antennas. I don't remember when it was that Mr. Bruce gave me this sheet with these instructions. These poles, I believe, were set about the first of April, 1930. Mr. Bruce gave me this sheet with these instructions some time before, perhaps a month or two, I don't know; I don't remember when. I have no record of that date. It was before the first of April, 1930. But I don't know the exact date.

This sheet 24 which has a sketch of a horizontal double V antenna is in my handwriting, and it was evidently rather a piece of scratch paper on which I calculated the length of wire to use to build this antenna. Between the four poles that the other sketch located, it was to have four elements as shown here, each one four wave lengths long at 16.11 meters, so that the wire length was 64.44 meters, and the [fol. 565] dimensions are shown on this sketch with the angles between the wires.

In this group of sketches here, page 26, was a sketch that I made to indicate to our shop force the details of erecting this antenna. At the end it shows the transmission line that went from the end of the antenna down the pole to the small building that housed the equipment to be connected to

Mr. Darby: And I assume, Mr. Brown, that you have no objection to having a statement appear on the record at this time, which I likewise understand is the fact: Reference heretofore has been made to the fact that an application of Mr. Bruce's is involved in interference with one of the patents in suit, and I think it is the second Lindenblad patent. Now, I would like to complete that statement with this fact, which namely is, that a reissue application of this patent that has been offered in evidence as Plaintiff's Exhibit 42 is involved in interference.

[fol. 552] Mr. Tunick: The reissue application of this particular patent, as far as we know, is involved in interference, but not on any claims in suit.

By Mr. Brown:

X Q. 312. Is it or is it not a fact that this rhombic antenna developed by you has revolutionized the construction of short wave sending and receiving antennas as built and used by the American Telephone & Telegraph Company since 1931?

A. It is my understanding that that type of antenna is replacing previous types.

Redirect examination.

By Mr. Darby:

The article which you hand me appears to be the same Levin and Young article of 1926 proceedings of the IRE volume 14, pages 675-688, to which I referred.

Mr. Darby: I offer the photostatic copy in evidence.

(Marked Defendant's Exhibit OO in evidence.)

John H. Couzens, called as a witness in behalf of the defendant, having been duly sworn, testified as follows:

Direct examination:

By Mr. Darby:

The Witness: I reside in Scarsdale, at the present time. I am associated with Bell Telephone Laboratories as patent

[fol. 553] solicitor and attorney. In 1926, my work as patent solicitor and attorney for the telephone company included antennas.

I wrote the letter dated 7/25/27 to Mr. Bruce, which is part of Defendant's Exhibit MM. I sent it to Mr. Bruce through the company mail.

I have seen a copy of the drawing Defendant's Exhibit JJ; to be exact, I saw it on Saturday, October 9, 1926. I witnessed a copy of that drawing. That is not my signature on that exhibit. I don't know what happened to the original copy that I witnessed, other than it is lost. I have endeavored to find it.

The facts set forth in this letter that I wrote July 25, 1927, are true.

Cross-examination.

By Mr. Brown:

The Witness: What I mean is that when I read the letter now, I think at the time I wrote it, I knew the facts as there shown. I would not say now that I remember all the facts without the letter; but I do recall the particular incident of writing the letter and also talking to Bruce about the tilted antenna.

Carl Robert Englund, called as a witness in behalf of the defendant, having been duly sworn, was examined and testified as follows:

Direct examination.

By Mr. Darby:

The Witness: I reside in Red Bank, New Jersey. I am associated with the Bell Telephone Laboratories. I am a member of the technical staff in charge of ultra-short wave [fol. 554] receiving work now. I have been employed by the Telephone Company in that capacity since 1914.

The nature of my work in 1926 to 1928 was entirely radio. I had something to do with antennae at that time.

I know Mr. Bruce. In 1926, Mr. Friis and I were supervisors in charge of the plant laboratory at Cliffwood, where Mr. Bruce worked. Technically, we were his immediate superiors.

The photostat of writing dated Friday, May 14, 1926, which you hand me is in my handwriting. I wrote it on May 14, 1926.

Mr. Bruce came in to see me in my office and discussed the work that he was doing at the time, and interested me in what seemed to me to be the multiple resonance effect that he was getting, so I asked him for details and he gave me the dimensions as noted down here on this paper—of his antenna. I later on made some calculations which complete the page.

In my capacity of supervisor or immediate superior to Mr. Bruce, I did not keep track of the work that Mr. Bruce was doing; Mr. Bruce was working more directly for Mr. Friis. He came in to consult with me on this particular occasion.

Mr. Darby: I offer in evidence the photostat of the record noted by the witness.

(Received and marked Defendant's Exhibit PP.)

The Court: When did you make these entries?

The Witness: I made these entries on the date written, May 14, 1926.

[fol. 555] Referring to a photostatic copy of a record dated August 10, 1928, in evidence in this case, as part of Defendant's Exhibit MM: the signature at the bottom of the page is my signature. As is customary in matters of this sort, Mr. Bruce came to me with this page and asked me to witness it and I signed it after reading it, as we usually do to make sure that I understood what it was about.

That is a technical matter for validating it.

Cross-examination.

By Mr. Brown:

The Witness: When Mr. Bruce told me about it, he did not tell me how these antennas worked. As I recall, he was a bit puzzled about what appeared to be some multiple resonance, and that is why I asked him for the details. Then he made some calculations, and then I think the matter lapsed. That was the point that seemed to be in his mind when he was showing this to me.

X Q. 20. When you say you understood the disclosure on these pages, that is what you understood?

A. The disclosure on that page is for two wires at an angle, with dimensions as given there.

When I said Mr. Bruce showed me the August 10, 1928, page, and that I read it over, and witnessed it, I meant by "witnessed it", I understood what Mr. Bruce had done, what was referred to by Mr. Bruce on that page. I do not know anything about the success of the antenna shown at the bottom of that page of August 10, 1928.

X Q. 23. Then your witnessing was, you simply read it over and signed the page?

[fol. 556] A. Mr. Bruce has here a diagram showing two legs of an antenna. In the center of each of those legs, an electromotive force is put. That is what I understood, the theory which——

X Q. 26. You looked simply at the page and understood that Mr. Bruce was telling you he had done something of that kind, but you do not mean to say you understood particularly how the thing worked, looking at that, do you?

A. That is what I say I understood, I understood how it was supposed to work, how it worked.

X Q. 27. Tell us how the diagram at the bottom of that page was supposed to work.

A. The wave impinging on the thing induces an emf in each of the legs and they are—the wire distance is a wave length longer than—let us see—3 lambda——

The principle involved, which is the thing that I understood at the time, is that of inducing emf's in conductors in such a manner that there would be a difference in the wire length to make up for them, to give the time lag so they would add up in series, the results would add up.

X Q. 28: You do not mean that, really, Mr. Englund, do you, because the very sketch you are looking at, shows the wires of equal length, doesn't it? Take another look at it.

A. No, but you see at the bottom of the page, the induced emf is directed to the right, in the center of the bottom leg, for example, there will be an electromotive force induced upwards. In the center of the top leg, there will be one induced downward, but the resulting current at the receiving point, since there is a difference in the wire length between them, will add up for the electromotive force.

[fol. 557] The explanation I gave you now, is how I understood from Mr. Bruce that that antenna works.

I do not believe directivity was mentioned.

Redirect examination.

By Mr. Darby:

The Witness: I went to see one of Mr. Bruce's antennas. That was the first exhibit, the original antenna on May 14, 1926. I went up to see the antenna a few days after that. I believe I did not see it in operation; it was just there.

Harold Trapp Friis, called as a witness on behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

The Witness: I reside in Rumson, New Jersey. I am associated with Bell Telephone Laboratories as research engineer. I have been so employed since 1919. From 1927 to 1930 the nature of my work was radio receiving work. That included specifically the subject of antennas.

I know Mr. Bruce. He worked for me in the company, associated in the work there.

Technically speaking, my rank relative to him, was nearest above him. I was the one to whom he immediately reported. I did not hold a sole position in that respect; Mr. Englund took part in that too. In general, I directed the work that was done by Mr. Bruce in antenna research. As far as possible, I kept myself familiar with the work that he was doing. In an organization of that type, where you [fol. 558] have a dozen engineers all doing research work in all kinds of lines, receiving sets, antennas, static measurements, measurement sets, attenuators, and so on, you cannot follow everything.

Referring to a written record of August 2, 1927, I recognize my signature on it. I recognize Mr. Bruce's handwriting. Bruce brought this record to me, or this page to me, and he asked me to witness it, as we used to do, and I read it through, understood it and signed it.

I also recognize the record of March of 1930. My signature is on that record as well. The circumstances of my signing that paper were similar to the circumstances in the other record. Mr. Bruce came in to me, or maybe I dropped

into his office, and he asked me to witness his suggestions here, this page. I read it through and understood it and witnessed it.

I did not keep familiar with the progress that Mr. Bruce was making, that is, the particular research work; I knew his work in general. I followed his work in general.

I knew what Mr. Bruce was doing in general throughout that entire period.

Cross-examination.

By Mr. Brown:

The Witness: I knew that the Bell Laboratories had been working on this problem of short wave transmission for a great many years. I knew too that they had been working on the problem of directive antenna for short waves for a great many years and that they had a number of skilled engineers during a number of years working on this problem, and leading up to the rhombic antenna of Bruce's.

[fol. 559] Alfred Charles Beck, called as a witness on behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

The Witness: I reside in Red Bank, New Jersey. I am associated with Bell Telephone Laboratories, Inc. I am a member of the Technical Staff. I have been so employed by the Telephone Company since early in July, 1928, I believe it is. The nature of the work that I was engaged upon when I entered its employ was mainly short wave antenna development. My immediate superior under whom I worked was Bruce.

You hand me a set of photostats. This record is dated 8/16/28. Some of this is in my handwriting and some is not. This page starts in and the date on the top part, the printing, is not in my handwriting, but as we come down I cannot say—I know that where it starts with the second group, one lambda tilt towards the oscillator, that is my

the antenna. It shows that three insulators were used there to space the wires, and that each wire of the antenna was connected to a transmission line.

During the month of April that antenna was located from those sketches, and sheet 26, dated April 24, 1930, is a description of some tests made on this antenna after the construction was completed.

This is a horizontal antenna, horizontal V, as indicated by the heading of this sheet, and the front end, which here means the end towards England, away from the equipment, was left open and the local oscillator tuned to 16.11 meters was located approximately 825 feet away, both in front and in back of this antenna, and in front the receiving set attenuator read 19.0, and in back it read 11.8, giving a ratio of 7.2, the difference in those two readings for that connection.

"The front end open" meant that the horizontal V, as tested then, simply the two wires ended at the end toward England, there was no connection to any other apparatus at all at that front end.

Then this sheet continues as a record of a test of April 29, 1930. The ratio of horizontal to vertical pick-up, front [fol. 566] end open, oscillator approximately 820 feet in front at 16.1 meters, and with the impedance, this says maximum coupling, etc., which indicates that the impedance between the antenna transmission line and the receiver was carefully matched; and the reading was 30DB, that is the ratio of horizontal to vertical pick-up, which means that the oscillator having short rods was used with those rods turned horizontally and vertically, and the impedances in the set were rematched at each time, and this reading shows 30DB.

We then took a frequency run on that antenna, and the first two columns give the beating oscillator setting of the receiving set. They merely indicate the tuning of the set, so that any of those could be duplicated if we wished.

The next column is headed "Oscillator Setting", and refers to the numbers on the dial of the oscillator.

The next column is "Wave Length", and the next "Megacycles", in which there are only two readings shown here.

Then comes the DB column, also the receiving set response to this particular setting of the oscillator.

Then on the same page, further to the right, are remarks about the operation of the equipment at that time and the

effects observed; that is where it starts "Where the oscillator setting is 10", and so forth.

This is in my handwriting. I had assistance from some of the other people in taking them, but I was conducting them; they were working under my direction for this particular test, and I took the notes. Everything on this page is in my handwriting, except the notation written at right [fol. 567] angles, which is in, I presume, Mr. Bruce's handwriting, because it is signed with his initials. I recognize his handwriting. I don't know whether Mr. Bruce signed this in my presence.

These tests on this antenna continued, and the next sheet here indicates the data taken, it is dated 5/1/30. It is page No. 33, and it is headed "Comparative measurements on G. B. U., set No. 14, two buttons pressed." "G. B. U." is the call sign designation of the British Post Office transmitter in, I believe, Rugby, England. I likewise conducted this test, and received messages from G. B. U. in England, 5/1/30. This record was made on that date.

The record has on the right-hand column the time, P. M., daylight saving time. It starts at 2:45, 2.46 and entries are there indicating for each minute down that column.

The second column says that with one volt in the set gain for 100 out—that is, the deflection—on the V—which indicates that this antenna was 79.0; at the bottom of that column it is entered again 79.0 showing that the gain of the receiver remained constant.

The next column is headed "Lambda over 2 82.5." That indicates the set gain of the other receiver used with the half wave vertical comparison antenna remaining the same.

The next column is the attenuation for 100 microamps output on the V, and that was read from the set each minute opposite these times.

The next column is labeled "Vertical lambda over 2", and the attenuations were read.

The next column is labeled "Required gain." That column is the difference between the set gain of the receiver [fol. 568] 79.0, and the attenuation read is for 100 out. Each attenuation was subtracted from 79.

The next column is the half wave required again and that was obtained in the same manner by subtracting the readings on the half wave from the set gain of the half wave.

The last column is headed "V over lambda over 2." There is a difference between the two preceding columns

It shows the gain in decibels when receiving this transmitter of this antenna over the half wave vertical.

This indicates that we were using two antennas, the horizontal V that I have just described, and the half wave vertical antenna. "E button pressed" means "two buttons pressed." These receivers are double detection receivers which have shunts in the intermediate frequency amplifier that can be connected across the circuit or disconnected by the use of push buttons on the front of the set and that notation was there to show that two of those buttons were pressed in at the time these measurements were made.

There were several people assisting at this time in this work. I made the measurements on the V, as I remember it. The measurements on the half wave vertical were, I think, taken with an automatic recorder at that time, and that was operated by one of our technical assistants, either Mr. Desmond or Mr. Chapman, I am not sure which. I don't remember that Mr. Lowry assisted in this work.

At this time we were evidently making monthly work reports. The work reports for April and May of 1930 appear to be these photostatic sheets, that is, sheets Nos. 27, 28 and 29, April, and sheets 30, 31, for May.

[fol. 569] Mr. Darby: I offer in evidence the pages referred to by this witness, pages 1, 2, 3 and 4, of August 16, 1928; the next page undated; the next page showing the pole layout, undated; the next page showing the rhombic antenna layout, undated; the next page showing the detail of transmission line connection to the antenna; next page, dated April 24th and 29th, respectively; next one dated May 1, 1930; the three pages of April's work report, and two pages of May's work report.

(Marked Defendant's Exhibit QQ in evidence.)

The Witness: Those two work reports are in my handwriting. I cannot definitely recall when I made them, when I wrote them out. It was our custom to make these during the first week of the next month, normally. They were certainly made in 1930.

Cross-examination.

By Mr. Brown:

The Witness: I began work with the Laboratories early in July, 1928, and after a short period of introductory survey, of course, I went immediately to work under Mr.

Bruce's direction, probably before the 1st of August that year. I am not certain of the exact date. I still am an assistant to Mr. Bruce. During that period of 1928, or on up to 1930, the short-wave antennas that I erected and tested for Mr. Bruce were mostly of the long-wire type. I did not work with any other type at that time. I believe I could say that I worked with a variety of arrangements of long wires to make up antennas for short-wave work.

[fol. 570] X Q. 64. Now, aside from your notes, do you feel you could describe all of those antennas now, and tell us what they were and what results you got with them?

A. That is a hard question. Those which had particularly interesting results, in general, I remember quite definitely, but I don't know, to tell you the truth, just what I am relying on for my testimony. I would not be positive in saying that I could remember all of them without referring to these notes. I would hate to remember this one without exact details. In general I know the performance of the different combinations. And Friday, when I testified about the notes of 8/16/28, that is, the series of antennas that were tested by me and Mr. Lowry, I believe I practically read everything from those notes in giving my testimony.

As I go through those various arrangements there that are referred to, the final figure or number seems to be expressed in minus units; for example, referring to the first one on the first page, it is minus 66 T. U. All of the measurements on these pages are measured in that same unit, and the best signals, or best results are those in which the minus number is smallest. Looking at the first two, minus 66 is not, I believe, as good a result as the second which is minus 63 and so on. On that basis, I believe, the best results that were obtained in that series of tests was of the one wave length single wire tilted towards the oscillator as shown on the first page and the last page, in each of which we get minus 63 T. U. And referring back to the first page, my third group of notes refers to a two wave length antenna of the V form in which the apex of the V is pointed forward [fol. 571] toward the oscillator and the open ends in the other direction, and the V in a vertical plane; that arrangement, I believe, is the second best of the results obtained in our experiments of August 16, 1928.

X Q. 75. I have examined these notes rather carefully and don't find in them anything that shows how your antenna

was actually supported. Is there anything to show that, I mean in the notes themselves?

A. The notation is written here, starting in the middle of that first sheet, "Top of pole," and then, "One meter from top of pole," which would indicate that it was supported on a pole. That is all it shows about it. I believe there is nothing to indicate where the receiver was connected to the several antennas.

Our last experiment in these notes was one in which the V was turned with the open end towards the transmitter, the V being arranged in a vertical plane.

X Q. 79. But as to that experiment you did not record any results, did you?

A. This is not in my handwriting, but I would interpret that the first reading indicated a result which was not completed on these notes. The notes do not show a completion; they show it was started and a reading was taken.

These notes of August 16, 1928, show, on that same sheet, the response in the case of a wave length wire tilting away from the oscillator. I do not know the number on that sheet; it is headed "Set No. 7." The first entry is the half wave lambda over 2 case 1 vertical. That notation shows that we put up an antenna composed of a wire of one wave length tilted away from the oscillator; that alpha 1, 22.7TU is the result. It would be assumed that this alpha 2 in case [fol. 572] of subsequent tests like that, the gain of the receiver would remain constant. That notice immediately above, in the notes, holds for that test. The two could be combined and give the results of tilting away.

There are several pages here which refer to a diamond-shaped wire, and some of them indicate one meter down, two meters down, and so forth. As to what I mean by this "one meter down" with reference to that antenna: this antenna was supported by a single pole through the center of this diamond-shaped antenna. The supports to the corners, front and rear corners, were held from the ground out a little distance by ropes attached to stakes, and the center was held by a rope which went through a pulley on the top of the pole. In this first test where it says "Top of pole" the rope that went up to the pulley on the top of the pole was pulled up so that the top insulator went as high as we could get it, and the sides were pulled out tight by means of guy ropes, out to stakes.

In the next one, "one meter down", that antenna insulator was lowered so that it came down one meter from the top of this pole, and then the guides to the side corners were tightened again so that a change in the interior angles of the diamond was obtained. Our receiver was on the ground or near the ground, and we lowered the top of our antenna from the top of the pole. The receiver was inside a small building. The ends of the antenna went through the wall of the building to the set, and we made tests at that time in several ways, several different ways of connecting those wires. These wires came from the lower apex or corner of the diamond to the receiver, in each case.

[fol. 573] I am certain that Mr. Bruce must have been familiar with this experimental work that we did in August of 1928, as shown on these notes.

Referring back to the receiver that was used with this diamond-shaped antenna, the receiver was not connected to ground. During some of the tests, I believe that the antenna was connected to ground.

As to whether or not the notes show that the loudest signals were had in each particular case when that particular antenna under test was highest on the pole: That is true for the V pointed towards the oscillator on the first page, and for the diamond-shaped antenna. I cannot say whether it is true or not for the one tilted away from the oscillator because the data is not complete to indicate that.

X Q. 96. Please refer again to your notes of August 16, 1928, and tell us, for example, the third group there is marked 2 lambda, and then there is the V on its corner. Does that mean that each leg of the V was one wave length, or does it mean that each leg was two wave lengths?

A. I believe it means each leg was one wave length, the total length was two wave lengths.

X Q. 97. As far as your notes are concerned, they are not definite on that, are they?

A. I would take it that that meant that from these notes. I would say the same thing about the diamond on page 3 of my notes. That is what I now interpret the notes to mean. I remember quite well, because the pole height was such that that length must have been used.

Referring to page 24 of my notes, which shows the layout of the posts or diagram from which I calculated the wires to [fol. 574] be used in the antenna: that figure shows a general

geometric arrangement of the antenna that is referred to in these notes that I have produced today.

Referring to my page 26, which speaks of a "horizontal Vee". Referring back to my notebook, page 24, "Vee" was a name that we used at that time for the entire antenna structure, although it was rhomboid or four-sided in effect.

When I speak, on my page 32, of the "horizontal Vee, front end open", I meant that the antenna was mounted on top of 70-foot poles, and the transmission line ran from the rear end of the antenna down the pole and into a building to be connected either to an oscillator or a receiver, according to the tests that we were making. Here it was usually the receiver. The other end was open. This transmission line was connected to one corner of this rhomboid figure at one of the acute angles. As to what I meant when I said that the other end was open, the sketch on page 32 shows the way the ends were constructed in this particular system. That is a top view shown here, and the little sketch to the right shows how the transmission line, which being broadside—a single wire and the circles would indicate that it was a two-wire open line. The circles are spacer insulators. At the front end there was no connection to those wires, they ended at that. The insulation arrangement was similar to that shown on this page.

X Q. 109. Now, referring to the middle figure, which contains the transmission line legend, that only indicates one line connected to one wire of the antenna, is that right, so far as the sketch itself goes?

A. No, in a drawing in that plane there are two indicated, [fol. 575] where it says "Antenna", the single line refers to two, as shown in the other. That is a view at right angles or a side view, whereas the other is a top view. This is a working sketch rather than a perspective drawing.

X Q. 110. But as a matter of fact, or as a perspective view, you will admit that that is equally consistent with there being only one transmission line and one antenna wire—I mean connected to one antenna wire?

A. Not when I see these two together.

The transmission line would not be visible in the lower sketch, coming directly under the crosswise insulator, more insulators of the same type, spaced it as it went down, as indicated by the circles on the other drawing.

I have described the connections at the acute angles of this rhomboid; at the obtuse angles, that is, the intermediate angles of the diamond, the two wires at those two angles were serially connected; in effect, just one wire bent around that corner.

On page 26, the middle of the page, under date of April 29, 1930, I say, "the ratio of horizontal to vertical pick-up, front end open"; by "ratio of horizontal to vertical pick-up" I meant that in that test an oscillator was placed approximately 825 feet in front of the antenna and tuned to 16.1 meters; a reading was taken first on the receiving set when the short rods which radiated the field generated by the oscillator were in a horizontal position. Then the oscillator was turned so that its rods were vertical and in effect a substantially vertically polarized wave was received by the antenna, and that was found after recoupling the receiver to the antenna and retuning to extract the [fol. 576] maximum energy in each case, to give 30 decibels less antenna output.

The first test of this antenna for receiving actual signals from a distant station, that is recorded here, was on May 1, 1930. I believe I testified that this notation on the side of the page of April 24, 1930, my mark 26, which reads, "This page important to Patent Department. First tests on horizontal rhombic antenna. E. B." is in Mr. Bruce's handwriting. It appears to be.

Those signals that we received from G. B. U. were received to test the performance of the antenna in commercial service. These signals were sent as part of the commercial transatlantic circuit of the Bell System. Therefore we felt that these tests would indicate the performance of the antenna in commercial use. That is, we were using commercially sent signals to test this particular antenna.

X Q. 122. And referring to your page 26 again, the lower part of which has a number of tabulated readings, as I understand it, the tests there recorded are a comparison of the effects of vertical as against horizontal polarization and not tests of directivity, is that right?

A. There are three tests indicated on that page. The first one at the top is a test of directivity; the second is a test of the ratio of horizontal to vertical pick-up, and the third is a frequency run. The second and third have nothing to do with directivity. When I say that the top of that page

indicates directivity, I mean that it shows ratio of front and back reception of a distant oscillator when the front end was open.

[fol. 577] LEWIS REEDER LOWERY, called as a witness in behalf of the defendant, having been duly sworn, testified as follows:

Direct examination.

By Mr. Darby:

The Witness: I am now employed by the Bell Telephone Laboratories. I reside at Red Bank, New Jersey. I am employed by the Bell Telephone Laboratories as a member of the technical staff. I have been so employed with the Bell Laboratories since June of 1927. The nature of my work, when I first entered their employ, was the investigation of various types of tilted wires under the direct supervision of Mr. Bruce. I was associated with Mr. Bruce in the work, and not with anyone else.

The nature of the work itself would be a comparison of the output of various elemental, simple forms of the V wire tilted in various manners, and endeavoring to find the maximum output in each case. The wires were used for a particular purpose in each case. The purpose of the wire was to, as I say, extract the maximum output of power or voltage in each case that we worked or attempted to investigate. I personally carried on that work under Mr. Bruce's supervision in 1927 and a portion of 1928.

I have a Bachelor of Science degree in electrical engineering from the University of Washington in Seattle.

After Mr. Beck had joined the company in 1928, I cooperated in some of the tests with Mr. Beck. These tests were very similar to the tests I had done in 1927, a continuation of the same type of research work. As to the [fol. 578] objective in making these various tests, it was the same general idea in each case; it was to conduct our elemental research on very simple forms of tilted wires to maximize the output in each case. There would be variations in lengths and various tilts of the simple forms, in each case attempting to find the maximum.

Referring to Defendant's Exhibit QQ, the top four pages of which bear the date August 16, 1928: part of the entries

on this page are in my handwriting; the other entries are in Mr. Beck's handwriting.

The work covered by this record is merely a continuation of the same work which I had been carrying on previous to the time Mr. Beck joined the organization. That record was made, according to the date shown in the upper right hand corner, 8/16/28. Apparently I co-operated with Mr. Beck on this test of 8/16/28; I believe all of the sheets herein refer to that date. After that time, I was engaged in testing other types of antenna, possibly not in co-operation with Mr. Beck. I am familiar with the work Mr. Beck was doing.

Q. 24. How was it possible for you to be familiar with the work that Mr. Beck was doing after your particular assignment to work with him had terminated?

A. Inasmuch as we were working under Mr. Bruce's supervision and along allied types of work, I would always have a general knowledge of the type of work which Mr. Beck was carrying on, although I may not have been engaged in it with him.

I was shifted to Homedale when the research work was shifted to that locality.

As to the fifth sheet in Defendant's Exhibit QQ that has a heading "Set No. 7," undated; not all of the entries [fol. 579] on the page are in my handwriting. The printing which starts lambda tilt toward oscillator—and I believe from there continuing on the rest of the page is in my handwriting. What is above that is in Mr. Beck's handwriting, I believe.

I was familiar with the erection of the rhombic type antenna at Homedale only in the connection that I was carrying on work on other types of antenna on a portion of the property immediately adjacent to the property where the rhombic antenna was erected. I was aware that the rhombic antenna was being erected. To the best of my knowledge, it was being erected in the year of 1930. I cannot give any closer approximation than that without recourse to such notes as I might have.

Cross-examination.

By Mr. Brown:

The Witness: Referring to the notes of 8/16/28, to the third page, where, at the top is shown a diamond-shaped

symbol, following the 4 lambda designation: in the test referred to on that page, the receiver was located in a small building immediately adjacent to the antenna. In back of this building, there was a pole which supported the antenna, at the top, by a rope running over a pulley, being connected to the antenna at the upper apex. The antenna was connected to the receiver in the building through the walls of the building. That was done by two short sections of wire. The receiver was not connected to the ground. According to the notes shown here, there is no designation showing other than that the antenna was coupled on at one turn off of ground of a six-turn coil.

[fol. 580] To my knowledge, the antenna was not only connected in this manner, it was connected both with one end grounded to the set and one end open.

Tests were made on this antenna with one of the lower wires connected to one turn of a six-turn coil. The other end was left open in some tests and in still further tests, it was grounded to the receiver set frame.

Mr. Darby: I offer in evidence copy of the file wrapper of the first Carter patent in suit, No. 1,623,196.

(Marked Defendant's Exhibit RR.)

Mr. Darby: I offer in evidence copy of the file wrapper of the second Carter patent, No. 1,909,610.

(Marked Defendant's Exhibit SS in evidence.)

Mr. Darby: I offer in evidence copy of the file wrapper of the first Lindenblad patent in suit, No. 1,884,006.

(Marked Defendant's Exhibit TT in evidence.)

Mr. Darby: I offer in evidence copy of the file wrapper of the second Lindenblad patent in suit, No. 1,927,522.

(Marked Defendant's Exhibit UU in evidence.)

Mr. Darby: I offer in evidence copy of the file wrapper of the third Carter patent in suit, No. 1,974,387.

(Marked Defendant's Exhibit VV in evidence.)

[fol. 581] Mr. Darby: I offer in evidence certified copy of the file wrapper and contents of Carter patent 2,027,020.

(Marked Defendant's Exhibit WW in evidence.)

LEO A. KELLEY, recalled.

Direct examination.

By Mr. Darby:

The Witness: In referring to the Bruce exhibits and the Bruce testimony, I intend to refer only to Exhibit MM and Exhibit JJ. These are the only ones that I feel are pertinent.

These tests related to short wave directional receiving antennæ, but it is well known that the principles which apply to reception apply as well as to the transmission of radio signals and in this respect all of the antenna patents in suit mention this same thing. For example, in the first Lindenblad patent, page 1, line 1, where it states:

"This invention relates to antennas and more particularly to directional antennæ for the propagation or reception of short wave signals."

In the second Lindenblad patent, on page 2, line 123, wherein it states:

"The antenna is equally suitable both for transmission and reception, the energy in the latter case to be collected and converged into the transmission line without the necessity of an impedance matching device", and again in the third [fol. 582] Carter patent, page 2, line 149:

"It is also to be distinctly understood that the unit so far described is not only useful for radiation purposes in a transmitting arrangement, but may be utilized equally as well for reception. That is, the antenna system, according to the present invention is equally well suited for any type of radiant action, whether it be collection of radiation energy or the transmission thereof."

Referring now to Defendant's Exhibit MM, there is shown in the second diagram from the top a receiver, short wave receiver, which Mr. Bruce said was somewhat directional, composed of two electrically long linear conductors. In this figure they are labeled two and a quarter wave lengths long, open ended, and inclined to each other at an angle.

If, in accordance with the teachings of these three patents in suit and what is generally understood in the art

anyway, the receiver marked R may be replaced by a transmitter, in which case the two electrically long wires inclined to each other, being open-ended, will be excited in phase opposition with standing waves. Therefore, if the first and second Lindenblad patents teach, that is, the second Lindenblad patent with particular reference to Fig. 2, teach what defendant is practicing, then their teaching in this respect is the same as Bruce has shown in this Exhibit MM.

Going to the third Carter patent, if I recall correctly, Mr. Hogan stated that the third Carter patent was distinguished [fol. 583] over the second Lindenblad patent in that, in the third Carter patent there was a rule given relating the electrical length of the sides of the V to the angle along the XX axis, as the patent puts it. And in that case I might refer to a passage in the patent on page 2, line 102, where it states:

"The angle alpha," alpha being the angle derived from the Abraham formula, "The angle alpha is the angle made by one of the conductors with the XX axis along which it is desired that the radiators AB propagate energy."

Now, Mr. Bruce, as a result of these early experiments, appreciated, so he testified, that there was some relationship between the length of the wires and their divergence. In order to get optimum results he devised a rule of thumb which is contained on Defendant's Exhibit JJ, to which I will now refer, this exhibit showing the Bruce rule relating the length of the wire to the angle of inclination.

Exhibit JJ was deduced by him some four months after the beginning of these tests as shown by the exhibits produced.

On this exhibit I find a number of lines which are tilted to the horizontal. These lines represent the various examples of the rule which Bruce was here setting forth, that rule being that for optimum results in the direction of the horizontal as here shown, these waves coming from the right, that the length of that wire should be one-half wave length longer than its projection on the horizontal, that is to say, on the direction in which the desired radiation was being received.

[fol. 584] The horizontal line that is shaded in this figure is marked "ground" at the right hand end. Mr. Bruce stated that he here meant perfect ground, so that the exhibit shows the relationship for optimum reception between the

inclined wire and its image in the ground, the optimum wave direction, the direction in which it was expected to receive best results, being on the bisector of that angle, in other words, as shown in this figure, parallel to the surface of the perfect ground.

Here is a definite teaching relating the electrical length of one side of a V-shaped antenna to the angle of the bisector for optimum results.

I have plotted the relationship which is given in the Bruce rule in the form shown in Exhibit JJ in a comparable form on a chart which included Fig. 12 of the third Carter patent. That is Exhibit W.

Referring to Exhibit W, the curve marked "Bruce angle" is the one which I plotted on this figure. The procedure for doing this was merely to use an obvious trigonometric relationship between the length of the wire and its projection on the bisector. The ratio of those two is simply the cosine of the angle. Consequently, one may plot the angle against the electrical length of the side by recognizing this simple trigonometric relationship.

Another way in which it might have been done would be to take the curves as actually shown by Bruce on that chart, and measure the angle and plot them against the length.

Referring again to the interchangeability of a transmitter and a receiver, Bruce, on Exhibit JJ, was showing the relationship for a receiver, but it is clear that this is [fol. 585] equally true of the transmitter; in other words, using Bruce's rule and a transmitter, one will obtain predominant radiation along the bisector of the angle between the wire and its image. It will be observed, on comparing the two, that is, comparing the curve on the Bruce angle, Exhibit W, with the curve specified by Carter derived from the Abraham formula, that they do not coincide.

Bruce's rule, it must be remembered, was a rule of thumb and was not derived by means of the Abraham formula, and it would not, therefore, be expected that it would coincide. The difference is not very great as can easily be seen on the figure. That is, for instance, at a length of four wave lengths there is a difference of about four degrees, and say at eight wave lengths there is a difference of about two to two and one-half degrees, and so forth.

Another thing is true: If one compares the predominant radiation obtained by using Bruce's angle with the pre-

dominant radiation also in the same direction using the angle specified by Carter, that in the latter case the radiation in that predominant direction will be somewhat greater. That is clear, of course, because that angle is derived from the Abraham formula and it is more rigorous than the rule of thumb method devised by Bruce.

Therefore, what is taught by the third Carter patent, as distinguished from the first two Lindenblad patents is also taught by Bruce, namely, this relationship between the length of the sides and the angle to the bisector between the wire and its image or the wire and the other side of the V.
[fol. 586] I have plotted the wire and its image, and I have stated that an antenna wire over perfect ground will cooperate with its image in the ground and if, for example, it is an inclined wire, then the radiation sent out by the combination of that inclined wire and its image in the ground, the radiation above the ground is exactly the same as would be obtained from two wires, one wire for the wire that was inclined above the ground and the other wire replacing the image; the two wires being excited in phase opposition and inclined with respect to each other in the same manner as the wire and its image.

In confirmation of this I wish to read a letter which appears to have been written by Mr. Lindenblad and which is contained in the File Wrapper of the second Lindenblad patent. It is so pertinent that I intend to read it in full.

Q. 1818. You have made a statement as to image, and your opinion on it. Now proceed from that point.

A. I wish to conclude that therefore, that Exhibit JJ, which shows the inclined wire above perfect ground, gives the Bruce rule and applies equally well to the wires having a V, removing the ground; that is all.

Cross-examination.

By Mr. Blackmar:

XQ. 1820. Referring to Defendant's Exhibit JJ, am I correct in understanding you that you understand the wire length in this case is derived by making the wire a half a wave length longer than the projection of that wire on the direction of expected signal?

A. Well, in this figure—no, not exactly—in this figure, the one to which I refer, Exhibit JJ, this wire is inclined to the

[fol. 587] horizontal, the horizontal here being perfect ground, and the wave direction, that is, the desired wave direction, being in the direction of that surface of the horizontal ground.

X Q. 1821. And did you not state in your direct examination that the wires were to be a half a wave length longer than their projection on the direction of the expected received signal?

A. Yes, sir, I probably did.

X Q. 1822. If the ground in this Defendant's Exhibit JJ were imperfect ground, practical ground, would the actual direction of incoming wave accord with the arrow labeled wave direction?

A. No; if you assumed imperfect ground, the arrow marked wave direction would probably not be or would not be in the direction shown there.

X Q. 1823. In general, what would be its direction?

A. It would be inclined at an angle downward, depending, of course, on the imperfection of the soil.

X Q. 1824. And then, under those circumstances, the wave direction would, as I understand it, run downward from the right to the left on this sheet Defendant's JJ, is that correct?

A. Yes, sir, that is correct, if you assume imperfect ground.

X Q. 1825. And in that case what would the angle between the wire and the horizontal be if its length were a half a wave length longer than its projection on the wave direction?

A. Assuming imperfect ground, that wire would be at a slightly wider angle, depending, of course, on the difference in wave direction.

X Q. 1826. That is the angle between the wire and the horizontal would be wider?

A. That is correct.

[fol. 588] X Q. 1827. In the case that I have been considering, namely, practical ground, where would the image of the wire be?

A. If you assumed perfect ground, the image of the wire will be, the optical image—that is, its position where the optical image would be if the surface of the earth were an optical mirror.

X Q. 1828. And, of course, assuming imperfect ground, is assuming practical conditions, is it not?

A. Yes, sir, it is assuming practical conditions, but, if I may so add, this is a teaching of Bruce, and he does not take the ground into consideration. He is showing what the relationship should be between the wire and its image with perfect ground. He specifically pointed out that he meant perfect ground, and I am not referring to any practical applications of it, but merely to the theory, the rule, that was deduced by Bruce, and the application of which is clear.

X Q. 1829. Am I correct in understanding that that theory so deduced, namely, that the wire should be a half wave length longer than its projection on the wave direction, would apply equally to a single wire in space?

A. Yes, in exactly the same way that using the Abraham formula, a single wire in free space could be so inclined that the principal lobe of radiation, or its equivalent in reception, that is, it would be receptive in that direction in a similar manner.

X Q. 1830. With practical ground, actual ground, referring to Defendant's JJ, as I understand, you stated that the wire would be at a somewhat greater angle with the horizontal?

A. Yes, sir, that is right.

X Q. 1831. And that also applies to the image, am I to understand?

A. Yes, sir, that would also apply to the image.

[fol. 589] X Q. 1835. Considering practical ground, the angle between the wire and its image is twice that between the wire and the ground, on the horizontal, and that angle is greater by twice the amount of the difference between the wire over practical ground as compared with over perfect ground, is that correct?

A. If you mean that as you change the wire to a new angle, let us say a wider angle, that the distance traversed, the distance in angle traversed is also traversed by the image, so that twice the angle exists as before, that is, in moving the wire, the image also moves, so that a given angle movement in the wire also is accompanied by the same angle movement in the image, and therefore the difference is twice.

X Q. 1836. And if that were shown upon Defendant's Exhibit W, that is in the case of practical ground with respect to Defendant's Exhibit JJ, am I correct in under-

standing that the upper line now labeled "Bruce Angle," would be further away from the lower line?

A. If you make these assumptions and ignore the fact that Bruce shows perfect ground, you are correct, that it will be somewhere above the curve marked "Bruce Angle."

X Q. 1837. Will you please refer to Defendant's Exhibit MM, I think it is, the Bruce notes of May 14, 1926? You referred, I believe, to the second figure on the page where the wires are marked 2.24 lambda?

A. Yes, sir.

X Q. 1838. Have you calculated the angle between those wires?

A. No, sir, I have not.

Mr. Darby: The defendant rests.

[fol. 590] Rebuttal Proofs

Philip S. Carter, called as a witness in behalf of the plaintiff in rebuttal, having been duly sworn, testified as follows:

Direct examination.

By Mr. Brown:

The Witness: I live in Port Jefferson, New York. My occupation is that of electrical engineer. I am employed by RCA Communications at Rocky Point Development Laboratories. I have been employed by the RCA and RCA Communications since 1920.

I am the patentee of the patent in suit, 1,974,387. The antenna that is disclosed in that patent that I have just mentioned is known as the Model D antenna. The idea of the Model D antenna was conceived some time prior to November, 1929. I fix the date of November, 1929, because I wrote a disclosure in a notebook at that time.

Q. 10. I hand you a notebook and three pages loose in the front of it, and ask you to point out in this notebook where the disclosure is found to which you have just referred?

A. These three pages are the original sheets removed from the notebook which I have in my hand, and in which

are carbon copies of the three original pages. This book is so made up that the originals can be removed for other use and the carbon copy is left for a permanent record in the book. Each page is made with a carbon. I have before me both the originals and carbons of those three pages that I am talking about.

These notes that are before me were written in that book on November 27, 1929. I wrote them myself. They are [fol. 591] in my handwriting throughout. I signed all three pages at the bottom, and all three pages were witnessed by Mr. H. E. Goldstine, on the same day. The date is November 27, 1929. Mr. Goldstine is an engineer who at that time was working with me on the antenna design and development.

He read the subject matter at the time he witnessed it, and I believe I explained the subject matter some time prior to writing these notes, as well as on the day that he witnessed them.

Q. 21. Would you state whether or not these three pages contain a disclosure in general form of the Model D antenna that is covered by the patent in suit known as the third Carter patent?

A. Yes, they do briefly describe the Model D antenna as described in the third Carter patent.

As to the disclosure that I made to Mr. Goldstine at the time I wrote those notes: the fundamental idea in this disclosure was a V arrangement of two wires, each being several wave lengths in length, and fed in phase opposition and arranged at the correct angle for their lengths in order to give maximum radiation in the direction of the bisector of the angle.

In addition to this fundamental unit, the disclosure related to several arrangements using the fundamental unit in order to increase the concentration of radiation both horizontally and vertically over that which would be obtained from a single unit.

Also it discloses an arrangement of two units, each of one or more V antennas, one located ahead of the other, along the line of the bisectors, the distance between the two units being an odd number of quarter wave lengths [fol. 592] and the two units being fed in proper quarter phase relation to give unidirectional radiation along the line of the bisector in one of the two directions in which it

was desired to radiate. What I have described in words is substantially the disclosure in the notebook.

I disclosed that idea of mine to somebody else at the time that I disclosed it to Mr. Goldstine. To the best of my recollection, I disclosed it, on the same day, to Mr. Hansell. That is the Mr. Hansell who has testified previously in this case. He was my superior during this work.

This letter which I have here was written by me on January 7, 1930, and addressed to Mr. C. H. Taylor, Vice-President in charge of engineering of RCA Communications. It concerns a patent disclosure which is attached and this patent disclosure covers this V type or Model D type antenna.

The building of this antenna was commenced some time, I believe, in December, and, at the time of the writing of this letter, it was under construction, as I stated in the letter. The photostatic copy of the letter which I have is one of an original letter written and signed by me. It was sent on January 7th. The disclosure of this invention which I just mentioned as being a patent disclosure, accompanied that letter to Mr. Taylor. This is a new disclosure which was written up for the Patent Department to use and make an application, and our standard procedure in all cases was to send these disclosures in to the vice-president in charge of engineering, for him to approve and send on to the patent department, if he wished.

Q. 35. Now, referring to the eight pages attached to your [fol. 593] letter of January 7th, to Mr. Taylor, what do you know about the origin of those pages and of the formula and diagrams that are included therein?

A. I will go through those pages in order to make certain that I will not make any mistake. On page 1, the figure was made by me and the typewriting copied from an original rough draft that I made myself, by our stenographer. On page 2, both of the figures were made by me. There are one or two notes written at right angles to the sheet which are not my writing. I believe they are Mr. Tunick's handwriting. (Mr. Tunick is our patent attorney handling this work.) The figure numbers are my handwriting. Page 3, the figure was made by me. All the writing on that page is mine with the exception of a note just above the apex of the V's, which is in Mr. Tunick's handwriting; that is, where it says "Leading odd number" something. On page

4, Fig. 5 was made by me with the exception of some of the letters pointing to some of the wires, which, I believe, were added later by Mr. Tunick. "Fig. 5" has been crossed out below the figure, and another figure, "Fig. 8", added. "Fig. 8" is not my handwriting, that is, the words "Fig. 8" written on the side after the original. The two little cross-cross figures at the right-hand upper corner of that page are not in my writing. Those labeled Fig. 10 and Fig. 10-A are not mine. I believe they were added later by Mr. Tunick. Going down the page, the figure originally labeled Fig. 6, with a line through it, was made by me, whereas the writing at the right of that, Fig. 9, I believe, is Mr. Tunick's handwriting, which he made after crossing out Fig. 6. The figure at the bottom of the page was made by me. The Fig. [fol. 594] 7 with a line through it is my writing, whereas Fig. 11 is not my writing. The writing in the corner, "Carter 4205", is not my writing. I believe it is Mr. Tunick's. On page 5, Fig. 8 was made by me. Figs. 9 and 10 were also made by me, and all writing on this page with the exception of a note just under the last line of typewriting are in my handwriting. That note, I believe, is in the stenographer's handwriting. On page 6 all the written material is in my handwriting with the exception of a note on the right-hand margin, which reads: "Gives rad." In something "direct" —I don't know what it means—direction. I believe that is Mr. Tunick's note there. I might also add with the exception of Mr. Tunick's signature on the bottom of the page, which, of course, is in his handwriting. Referring to the bottom of the page, that is my signature.

I signed that on January 4, 1930.

On page 7 both the figures were made by me, and all printing and handwriting on that page are mine with the exception of Mr. Harry Tunick's signature. This page bears my signature and was made on December 7, 1929. The figures on that page were made by me either on December 7, 1929, or prior to that date.

On page 8 all printing and handwriting are mine, and I made the curve and figure shown on this page. This curve was made on or prior to November 29, 1929. The date that is on this page is in my handwriting. That is my lettering of my name and my initials to the right. There is one note, small note, in the right hand margin near the top which is not my handwriting, I believe it is Mr. Tunick's, where it

[fol. 595] says Figure 12. Also Mr. Tunick's signature at the bottom of the page is not my handwriting.

Speaking generally of these pages 1 to 8, they are the pages which were attached to and sent with my letter of January 7th to Mr. Taylor.

This letter was written by me on May 9, 1930, signed by me on the same date, and sent to Mr. Harry Tunick of our Patent Department on that date. Accompanying this letter were a few sheets containing a little more detailed explanation concerning some points in the form of the disclosure sent in Mr. Taylor's letter. The three sheets which follow my letter of May 9, 1930, and attached thereto were the sheets that were sent with that letter. Those sheets were made up on or prior to May 8, 1930. That is my signature to these additional sheets.

The first paragraph of my letter of May 9, 1930, reads:

"Due to the pressure of other work mostly in connection with tests and adjustments of the antenna system covered by the above document, I have been delayed in the writing of a more detailed outline of the principles involved in this system."

As of the date of this letter, the antenna had been constructed, had gone through its initial adjustments, had been used for local tests, and the first series of long distance tests between Rocky Point and our receiving station at Marshall, California, had been completed; so that at that time we had reached our decision as to the relative merits of this antenna.

The nature of the first tests prior to the date of this letter were tests made in conjunction with adjusting the an- [fol. 596] tenna in the field in order to give what we expected to get out of it, locally. I think they were started toward the latter part of February and were completed some time during the following months.

Then the test to Marshall, Cal., the long distance test, was started toward the last of April. This antenna was directed on Marshall for this particular purpose. The test to Marshall was conducted during the early part of 1930. In those tests, we had a transmitter located in our development building at Rocky Point; we had this so-called model D antenna connected to one transmission line, running into the building; to another transmission line we had a half wave di-pole connected, and it was of the same mean

height as the model D antenna, and then we had switches provided near the transmitter in the building, so that we could very quickly switch from one antenna to the other. During these tests we switched back and forth between the two antennas, usually at the end of every five minutes.

At the beginning of a five minute period, we sent a message to Marshall giving the number of the particular test, and then proceeded to hold a long dash on the transmitter for them to make measurements. This was done so that the people measuring at Marshall would not know which antenna they were listening to. That would iron out any psychological effect on the operators out there that might come into the test. We wanted the people who were receiving at the other end not to know which of the two transmitters was sending. To keep them from getting onto the order and then knowing, we switched that order quite often. Sometimes we would run the same antenna two five minute [fol. 597] periods in succession without them knowing it, of course, and simply identifying the periods by numbers.

I have referred to this antenna that was constructed early in 1930, and on which we ran the tests just referred to, simply as a model D. This particular antenna consisted of four V wire units. There were two sections, one located behind the other, and in each of those sections, there were two V units, one above the other, separated by a half a wave length. These were built on 80 foot poles. The wires were eight wave lengths long, and the angle was 35 degrees between the wires of a single V and the spacing between the forward and after units was two and a quarter wave lengths. They were fed in phase opposition in a way which is mentioned in the disclosures.

That is the antenna I was talking about as having been constructed and tested in my previous testimony.

This next letter in this file is a letter from Mr. Harry Tunick to me, dated May 14, 1930. It is simply to the effect that he is forwarding me a rough draft of United States patent application papers, covering the V type antenna, which I have been discussing. Then follow a number of pages which are entitled "Docket No. 4205," concluding with two sheets of drawings, all marked "Docket 4205"; these are the sheets which were attached to his letter, and they contain the rough draft of the patent application as he submitted it to me. I received that letter

with that rough draft within a day or two after the date of his letter.

The next letter in the file is a letter from me to Mr. Tunick, dated May 20, 1930, and was written in answer to the letter which we just mentioned. It contains several com-[fol. 598] ments I made upon the rough draft of the specification that was sent by Mr. Tunick, and some suggestions for changes. I signed and sent that letter on or about May 20th, the date it bears. That is my signature on page 2.

The next paper in the file, dated May 24, 1930, is a letter from Mr. Tunick to me, simply to the effect that he is sending me the final application papers covering this invention, that is, the V type antenna system. I received that letter with the final form of application on or about May 24th.

The next letter was written by me to Mr. Harry Tunick, and it is a letter sent with the patent application papers after having been signed by me, that is, the patent application papers were sent by me, forwarded with this letter. That is the letter with which I returned the executed application.

Mr. Brown: If your Honor please, I would like to offer as a single exhibit, Plaintiff's Exhibit 43, the file of papers that have been referred to by the witness, consisting of:

Letter of January 8, 1930, from Taylor to Grover.

Letter of January 7, 1930, from Carter to Taylor, with the attached patent disclosure as referred to by the witness.

Letter of April 1, 1930, from Tunick to the Patent Department.

Letter of May 9, 1930, from Carter to Tunick, with three attached sheets signed by the witness and referred to in his testimony.

Letter of May 14, 1930, from Tunick to Carter, with an attached rough draft of his specifications and claims and drawings in sketch.

[fol. 599] Letter of May 20, 1930, from Carter to Tunick.

Letter of May 24, 1930, from Tunick to Carter.

Letter of June 5, 1930, from Carter to Tunick.

(Marked Plaintiff's Exhibit 43 in evidence.)

The Witness: I have referred to certain tests of this Model D antenna working with Marshall, California; I made a written report of these tests and of the performance of that antenna as observed by me during the early part

of 1930; along the early part of May, 1930, I made a report covering the first few days of tests with Marshall. This is the report I made at that time. This report was given to Mr. Hansell, who was in charge of our work at Rocky Point at that time, to do with as he wished. This report was made by me; the drawings were made by me. That is my signature at the end of the report. It was signed May 6, 1930. I recognize that as a copy of a report I handed to Mr. Hansell on or about that date.

In all three of these charts attached to this report, the diagrams show the received signal strength at Marshall in decibels above one microvolt per meter as a reference level. In each one there are two curves, one being the received signal intensity for the horizontal half wave di-pole, and the other being the signal from the new type V antenna. They show the relative gain of one antenna over the other. These graphs show a very successful performance of this Model D antenna as compared to the half wave di-pole. In fact, at the top of two or three of these tests the power [fol. 600] ratio at the receiving station runs from 59.5 up to as high as 83.2, that is, the signal from the V antenna was in the latter case 83.2 times as strong as that from the half wave di-pole.

The first test chart is dated April 25, 1930, the last one was May 1, 1930; the others all lie in between those two dates.

As a result of the performance of this Model D test antenna, as recorded on those charts, I made, along with this report, a recommendation that this new type of antenna be substituted in place of several antennas which we had on schedule at that time for new construction. That recommendation is contained in the last three paragraphs with a heading "Recommendation" in this report.

The report was made on or prior to May 6, 1930.

Mr. Brown: I offer in evidence as a plaintiff's exhibit, the report entitled "Transmission Tests Model D Projector" just referred to by the witness.

(Marked Plaintiff's Exhibit 44 in evidence.)

The Witness: You hand me a copy of a letter dated March 22, 1930; this is a letter written by me and addressed to Mr. H. B. Morris, who was then in charge of the construction work at Rocky Point. The subject at the head of the

letter was: "Experimental antenna, new type." To the best of my recollection, at the time of the writing of this letter, we were already making the first tests and adjustments, on this V-type antenna; and this letter was written to Mr. Morris thanking him for the cooperation which his division had been giving us in getting this antenna con- [fol. 601] structed, and so forth. This letter indicates that prior to its date the antenna had been completed. The date is March 22, 1930. The letter indicates that the antenna has been constructed. It so states in the letter. That is my signature. I wrote, signed and sent that letter on or about March 22, 1930.

Mr. Brown: I offer this letter in evidence.

(Marked Plaintiff's Exhibit 45 in evidence.)

Mr. Brown: I offer in evidence as a plaintiff's exhibit a photostatic copy of the three pages from the Carter notebook dated November 27, 1929, referred to by the witness in his examination.

(Marked Plaintiff's Exhibit 46 in evidence.)

Cross-examination.

By Mr. Darby:

The Witness: With respect to all of the statements contained in the letters, reports or memoranda that I testified about in my direct examination, and contained in Plaintiff's Exhibits 43 to 46 inclusive. I believe they correctly stated the facts and my beliefs at the time that I wrote them, with the exception of one possible, one or two possible minor errors which were corrected in a later letter. You ask me to point out the errors. In the original disclosure, attached to the letter to Mr. Taylor, the vice-president in charge of engineering, and dated January 7, 1930, there is an error in the formula on page 6. Under the radical there, where I have "cosine theta one," it should have read "sine theta [fol. 602] one", but that was corrected later in the sheets attached to the letter to Mr. Tunick, dated May 9th, and I believe that the formula there at the top of page 7 is correct. That is the only error which I know of right now. There might be others. That formula was copied from my orig-

inal disclosure and that error was simply a mistake in copying. I thought I had copied it correctly, but I had not.

With that exception, I think that everything stated in these letters or reports or memoranda that I wrote, correctly expressed my belief at the time they were written.

The antennæ we constructed were erected on 80 foot poles.

They were the standard size poles obtainable; we had a large number of those poles at Rocky Point; we had been using them before that. They are the standard size for telegraph poles. I believe you are right in stating that the longer-sized poles come from the West Coast; for that reason an 80 foot pole is what is ordinarily used here in the East, because of the expense incident to getting taller poles.

In my letter of May 9, 1930, to Mr. Tunick, the three sheets, numbered pages 5, 6 and 7, are, to the best of my knowledge, the only sheets that were transmitted with that letter. I believe there were no sheets numbered 1 to 4, inclusive. The intention was to substitute these three sheets in place of the former three sheets which had been sent in with the original disclosure—explaining the same thing. I went into a little more detail here and made the correction to the formula which I just mentioned.
[fol. 603] With respect to the figures or drawings in the various sheets and papers that I testified about and made at that time. I certainly think those figures and drawings correctly represent what I intended them to represent at the time that they were made. That is, it was my belief at the time that they were made, that they were correct representations.

X Q. 118. With reference to Mr. Tunick's letter to you of May 14, 1930, where he sent you the draft specification, a copy of which draft is attached to Mr. Tunick's letter to you, is the draft as it now is in the same condition as it was when you received it from Mr. Tunick? That is, did you make any corrections to the draft yourself?

A. I am not certain without looking it over very carefully. Most of these corrections are in Mr. Tunick's writing. In going over these in a hurry now, I haven't found any correction I recognize as my writing. I believe that I received this draft from Mr. Tunick in exactly the condition as it is shown by these photostatic pages.

My purpose in going over this rough draft was to check it for accuracy, and to make suggestions of changes. I either changed it to conform with my idea or I accepted it in the form that Mr. Tunick had changed it. In its present condition, as represented by the photostatic copies, it was not entirely acceptable to me as correctly describing the invention that I believed I had made; in the following letter, which I believe you have there, dated May 20th, I wrote Mr. Tunick and mentioned several points which should have been changed. I went over the draft and simply wrote a letter concerning the changes.

[fol. 604] X Q. 126. I hand you the original draft of specification from which the photostats have been made, and will you please check over the red pencil notations on that draft so as to enable you to state whether or not they were all made by you?

A. Yes, all the writing in the red pencil is mine.

Mr. Brown: Suppose we just later take the copy of Plaintiff's Exhibit 43 which is in evidence and underline it in red to indicate that which was written in red.

Mr. Darby: That will be entirely agreeable.

The Court: If you will just indicate on the copy that is in evidence what was in red, that is all that the difference is, then there is no necessity for having the original.

Clarence W. Hansell, recalled in behalf of the plaintiff, in rebuttal, further testified as follows:

Direct examination.

By Mr. Brown:

The Witness: I am the same C. W. Hansell who has testified in this case.

I will tell you what I know about the origin of the Model D antenna, that is my own direct knowledge about it, during the period from late 1929 through up to May of 1930: During the latter part of 1929, Mr. P. S. Carter was engaged under my general direction in the design of antennas for commercial service, and, whenever time would permit, in calculations aiming at determining the characteristics of

other types of antennas than those which we were using at that time.

[fol. 605] Some time in the last quarter of 1929, his calculations indicated that a V antenna of the type involved in this suit should be a very promising subject for development. His calculations indicated that the directivity would be very considerable.

He proposed to me that we set up a full-scale model with which we could make tests over a long distance to determine the effectiveness of that type of antenna.

It was evident to all of us at that time that if the antenna would give the amount of directivity which Carter predicted, it would be very much cheaper to build in respect to directivity per dollar than models which we had used previously.

Right at this time, I can't recall the specific date on which he disclosed it to me, but I do remember making arrangements for the expenditure of money necessary to build the antenna some time in the latter part of 1929. At that time, I was the head of the department in which Mr. Carter was working. It was necessary for me to make the arrangements for the erection of that antenna.

According to my recollection, the first part of the construction of the Model D antenna, embodying this new idea of Mr. Carter's, was begun probably in December of 1929, and continued until about March, 1930. I know about the testing of that antenna. In some of the very first tests made locally on the antenna, I assisted personally, and then, a little later when we were making tests, between Rocky Point and Marshall, California, I, of course, kept myself familiar with the tests, and on some occasions, personally operated the transmitter used in the tests. I heard [fol. 606] Mr. Carter testify that these tests were made in April; that accords with my recollection.

This letter dated March 21, 1930, bears my signature at the bottom. That letter was written, signed and sent by me on or about the date that it bears. This letter states that we had completed the construction of what I called our modified type horizontally polarized harmonic antenna, which was suggested by Mr. P. S. Carter; the antenna that I referred to there is what we now know as the Model D, which was this V-type antenna involved in this suit. It

shows the antenna had been constructed before that date of March 21, 1930.

You show me a carbon of a letter, dated March 31, 1930; this is a copy of a letter sent by Mr. R. R. Beal, manager of the Pacific Division, to Mr. C. H. Taylor, vice-president in charge of engineering, advising that the receiving station at Marshall would be in a position to make the measurements on this antenna, which we had requested. This is a photostat of the copy which was sent directly to me by Mr. Beal at that time. I received the original shortly after March 31, 1930.

I actually saw this Model D antenna that was built early in 1930. This was the only antenna at Rocky Point of a construction that could possibly have been referred to by the description Model D antenna during that period.

This letter, of which you hand me a copy, was written by me on May 7, 1930, to Mr. H. H. Beverage, Chief Engineer, for the purpose of transmitting Carter's report and results of the first series of tests made on this Model D antenna. Mr. Carter's report was dated May 6, 1930, and is part of Plaintiff's Exhibit 44. That is my signature on that letter. [fol. 607] I wrote, signed and sent that letter on or about the date it bears. The original of that letter was sent to Mr. H. H. Beverage, and I was so proud of the results of this test that I sent out a large number of copies, as indicated on the original letter. One was sent to Mr. C. H. Taylor, vice-president in charge of engineering, and an extra copy to Mr. Beverage. There was a copy sent to Mr. J. H. Shannon, who was at that time in charge of lay-out and station design, and a copy to Mr. Hallborg, engineer in our New York office, and one copy to Mr. Carter and one to Mr. Tunick of the Patent Department. Mr. Beverage is my next superior in the organization of RCA Communications.

The results on which Carter's report was based and the report itself, which was sent with my letter, indicates that this antenna was more satisfactory than any model we had had available up to that time, and that it should be used for all new construction.

Mr. Brown: I now offer in evidence letter dated May 7, 1930, to Mr. Beverage.

(Marked Plaintiff's Exhibit 47 in evidence.)

Mr. Brown: I also offer in evidence at this time, as a plaintiff's exhibit, a letter of Hansell to Beverage, dated March 21, 1930, and frequently referred to.

(Marked Plaintiff's Exhibit 48 in evidence.)

According to my recollection, the Model D antenna, as I have stated I saw it early in 1930, was made up of a com- [fol. 608] bination of four V type radiators. Each element of the antenna, that is, if we divide the antenna into two general parts, was made up of two V's, each V a number of wave lengths long and fed with currents in phase opposition, set at an angle of 35 degrees.

Two V's in each element were mounted one above the other at a distance of one-half a wave length and excited co-phasially, and behind that combination was another combination of two V's spaced along the general direction of the bisector a distance of nine one-quarter wave lengths and the two elements were then excited in phase quadrature to give a unidirectional beam of radiation out in the general direction of the bisector from the apices toward the open ends of the V's. Observations were made on the North Star, by which the antenna was laid out in a direction on the Great Circle Path to Marshall. By that I mean that the line of the bisector of the V's of this antenna pointed in the Great Circle direction of Marshall.

When I said "angle of 35 degrees," I meant the angle between the two wires of each V was 35 degrees, corresponding to a half angle of 17½.

I was thoroughly familiar with this antenna at that time. Each V unit of that antenna was in a horizontal plane.

Mr. Darby: No cross-examination.

[fol. 609] HALLAN GOLDSTINE, called as a witness on behalf of the plaintiff, in rebuttal, having been duly sworn, testified as follows:

Direct examination.

By Mr. Brown:

The Witness: I live at Port Jefferson Station, New York. I am working as a radio engineer for RCA Communications.

I am a graduate mechanical engineer, University of Kentucky. I have been working for RCA Communications since about October, 1928, at Rocky Point. I came with the company first of July, 1928.

During the time I have been with RCA Communications, I worked with Mr. P. S. Carter for quite a period,—the last part of 1929 and first part of 1930. I am familiar with what was known during early in 1930, as Model D antenna at Rocky Point.

Plaintiff's Exhibit 46 consists of three pages from Mr. Carter's notebook which I witnessed and signed. I first saw those three pages or the originals thereof on the date given here,—November 27, 1929. That is my signature on the bottoms of the three pages. I wrote that signature on those pages on the date given here, on November 27, 1929. As to why I wrote my name on those pages: Mr. Carter gave me these, in his notebook, and explained the operation of this antenna, and I read this disclosure given here, and, reading it and understanding it, I signed it to witness the fact that I had understood it.

Shortly after this date a Model D antenna was constructed near the experimental building. I helped Mr. Carter adjust and make measurements locally on this antenna, and [fol. 610] then, at a later date, I think it was some time in April, around the first part of April, and during April we ran some tests to Marshall, California, and I took care of the transmitter on those tests. We had two antennas, this one, the Model D, and another antenna, and we would send out signals to Marshall. Before each transmission we would give an identifying number so that we could tell which test it was by the number given, so that they wouldn't know which antenna was on, but we could identify them by the number; and then we would leave the transmitter on a steady dash for the rest of that period of five minutes, and then we would change over to the other antenna and continue that throughout the day, and we received messages back from them that they had received the readings, and I helped calculate and plot some of those readings. I can send and receive telegraph code. I actually sent the test messages to Marshall; I took care of that; for each transmission we would have to send an identifying number.

Mr. Darby: No cross-examination.

Harry Tunick, called as a witness on behalf of the plaintiff, in rebuttal, having been duly sworn, testified as follows:

Direct examination.

By Mr. Brown:

The Witness: I reside at Rye, New York; my occupation is that of attorney. I am employed by the plaintiff as Division Patent Attorney in their Patent Department. I have been an attorney in the Patent Department since 1926, and [fol. 611] Division Attorney since 1932. I was an attorney in the Patent Department of the Radio Corporation in January, 1930. That continued until after June of 1930.

You hand me Plaintiff's Exhibit 43 in this case: I recognize the signature of Mr. C. H. Taylor on a letter addressed to Mr. H. G. Grover, the letter being dated January 8, 1930. Mr. Grover was the patent attorney for the Radio Corporation. I was one of his assistants.

I know that it is the custom of the Patent Department to stamp all letters on the date that they are received, and according to the Patent Department's stamp, this letter was received on January 9, 1930. In the upper left hand corner of the letter there is a pencil note to Mr. Carlson, initialed H. G. I recognize the writing to be that of Mr. Grover. That note asks Mr. Carlson to please acknowledge and docket for Mr. Tunick. I am the Mr. Tunick there referred to. Pursuant to that note, that letter and the enclosures with it came to me some time on or before January 16, 1930. As these disclosures came to me, and after I had read them, it was my custom, and still is, to sign them and date them as of the time of reading them. I signed and dated that particular disclosure on January 16, 1930. That is my signature at the foot of it.

Having examined that, I can state that at that time I had read and understood that disclosure as of that date. I know that to be a fact for the reason that up to that time I had been in charge of the patent application work relating, among other things, to antennas.

At this time I handled all of the patent application work originating at Rocky Point, and it was my custom to make [fol. 612] trips out there carrying various dockets in order to discuss them with the engineers from various viewpoints. Apparently, according to the letter dated April 1, 1930, which I dictated on that date and which I signed on that

date and which forms part of this Exhibit, I had been out to Rocky Point and discussed the disclosure with Mr. Carter. I recall asking Mr. Carter to let me have the equation for the curve appearing on sheet No. 8 of this Exhibit, which I signed on January 16, 1930. I believe subsequent correspondence will show that Mr. Carter furnished me with that equation.

On May 10, 1930, I had witnessed, after reading and understanding both a letter of May 9th, 1930, sent to me by Mr. Carter, and attached to that letter were some sheets which I also witnessed and dated and understood, as of May 10, 1930. On sheet No. 6 there is given an empirical formula reading: Alpha equals 50.9 (1 over lambda) to the minus 0.513 degrees. This I understood to be the equation for the curve given with the original disclosure to the patent department, which I have referred to as sheet No. 8, and which is entitled, "Correct angle", and witnessed by me on January 16, 1930.

Some time before May 14, 1930, I prepared a rough draft of the patent application covering Mr. Carter's invention as described in the original disclosure sent to the Patent Department some time in the early part of January. It was received in the Patent Department on January 9, 1930. The rough draft had been dictated some time before May 14, 1930, and revised in pencil by me and sent out on May 14, 1930, to Mr. Carter.

[fol. 613] This rough draft which is contained in this file has a number of pencil changes thereon, which Mr. Carter has said are in my handwriting. These changes were made before this draft was sent to Mr. Carter. There is no substantial change in the specification and claims as I drew them from the disclosure of January of 1930.

I notice that on May 21st we received at the Patent Department an additional letter from Mr. Carter returning his rough draft. I added portions of this letter to the original rough draft, as indicated by the remarks "Insert 1", "Insert 2", "Insert 3", on page 1 of that letter, and "Insert 4", on page 2 of that letter. I believe these inserts added somewhat to the material already in the original rough draft. Now, with the inserts made, on May 21st, I find that I sent to Mr. Carter a final draft for him to execute. I also enclosed a check for one dollar which covered the nominal consideration for assigning this case to the Radio Corporation. On June 6th, I received another letter from Mr.

Carter enclosing the executed patent application. This application was filed in the Patent Office June 11, 1930, and given Serial No. 460,467 and resulted in the third Carter patent in suit, No. 1,974,387.

The letters which appear in that file were written, signed and sent by me on or about the dates that appear thereon. And the letters addressed to me from Mr. Carter were received by me on or shortly after the dates that they bear.

On most of the documents in that file, the notation "Docket No. 4205" appears; that indicates the folder number in which Mr. Carter's invention was placed. It is the Patent [fol. 614] Department reference number. In other words, it is the file number under which correspondence, and so forth, would be filed.

Cross-examination.

By Mr. Darby:

The Witness: A division attorney has charge of a group of attorneys. That is, he has charge of a division of attorneys. I may add that in the division that I have charge of that deals mainly with those inventions lying in the field of radio communication, long-distance communication.

It is my custom and has been, and the instance concerning which I have testified was no exception, to study a disclosure, read it and understand it, before I sign it. So that every one of these documents that I witnessed, that is, bearing on this Carter invention, every one that I witnessed I understood before I signed. The understanding that I obtained from these disclosures to me was reflected in this draft specification that I sent to Mr. Carter; it was fully and accurately and completely reflected therein.

Mr. Blackmar: I offer in evidence Plaintiff's Exhibit 34 for Identification and also Plaintiff's Exhibit 36 for Identification, both being sketches which were referred to by the witness Kelley in the course of his cross-examination.

(Marked Plaintiff's Exhibits 34 and 36, respectively, in evidence.)

Mr. Brown: Mr. Darby offered in evidence a certified copy of the File Wrapper and contents of Carter patent 2,027,020. [fol. 615] You may remember I raised the question of the purpose, and Mr. Darby answered that they were offered to

show estoppel. He offered an additional file history of a patent not in suit, a later patent to Carter, and if your Honor please, I wish now to object to that Exhibit WW, the file history of patent 2,027,020, and to move to strike it out as being irrelevant, immaterial and incompetent to any issue in this case.

The Court: Well, I will take it. I will see whether it is admissible for any purpose. If it is, I will consider it in, and if I do not think it is admissible, I won't.

JOHN V. L. HOGAN, recalled in behalf of the plaintiff in rebuttal, further testified as follows:

Direct examination.

By Mr. Blackmar:

Q. 935. Please refer to the Brown British patent, No. 14,449: does this patent disclose or teach the use as radiating elements of an antenna of wires several wave lengths long?

A. No. Fig. 1 of the Brown patent, for example, shows a spark transmitter, and such a spark exciter will cause the vertical wires to oscillate at their fundamental frequency, that is to say, they will be fundamentally excited in this transmitter, and thus the wires would each be one-quarter wave length long.

Q. 938. Is it possible to secure, with the system shown in this patent, directivity that is comparable to that which can be secured with Lindenblad's long wires, referring par- [fol. 616] ticularly to the first Lindenblad patent?

A. No, it is not. With short wires, one would have to use a multiplicity of radiators or antenna sections, and they would have to be lined up and phased in order to give high directivity. The arrangement illustrated in Brown would not give high directivity.

Q. 939. Were systems in which antennas of the type shown in Brown, the general type shown in Brown, used in multiple or in arrays, in practical use in the art, prior to 1928?

A. Yes, if we assume Brown to have shown the equivalent of half wave di-poles, for example, a multiplicity or array of short wires like that is the basis of the British beam di-

rective antenna or the model A directive antenna or of other curtain types of directive antennas.

Q. 940. Please refer to the Levy French patent, No. 593,-570 and the patent of addition thereto, No. 30,798: first referring to the patent of addition, do you find anything indicated there, that indicates the length of the wires in Fig. 1 thereof?

A. Yes. In the first paragraph of the patent of addition, Levy says that modifications of the arrangements shown in the parent patent may be made and that, for instance, wires 1 and 2 of the arrangement shown in the Fig. 1 of the parent patent, instead of being parallel in one direction, could form, between themselves, any desired angle. Then he says that Fig. 1 of the drawing of the patent of addition represents such an antenna. Referring to the original patent, Fig. 2 is a diagram which illustrates the distribution of current in the antenna of Fig. 1, that is to say, of Fig. 1 of the original patent, and also of Fig. 1 of the additional patent, which is simply Fig. 1 of the original, differently disposed. That Fig. 2 shows a quarter wave of [fol. 617] current on each of the two halves of the upper part of Fig. 1 antenna, and thus fixes the length of the entire span from pole to pole in Fig. 1 of the patent, as one-half wave or of the antenna as being made up of two quarter-wave wires.

Q. 943. What do you understand the teaching of Levy to be with respect to the angle between the net works 1 and 2 of Fig. 1 of the patent of addition?

A. That between the two sections, there is to be some angle less than 180 degrees, and as he says, particularly a right angle, that is to say, the only specified case is that of a right angle, but it says generally it may have any angle smaller than 180 degrees.

Q. 944. Please compare Levy's use of several parallel wires in each of his net works 1 and 2, as shown in Fig. 1 of the patent of addition, with Carter's use of several parallel wires in, for example, Figs. 4 and 5 and 11 of the third Carter patent?

A. Yes, in the Carter patent, the wires shown in Figs. 4 and 5 and 11 are carefully placed, one directly above the other, and one exactly like the one below it, and moreover, the energy to feed those wires is brought into a mid point end connection, symmetrically, so that the current in the two wires will be in the same phase and of the same amount

and both the wires will be placed and driven in a perfectly symmetrical way vertically. In that case, as I pointed out, the radiation measured in the horizontal plane will be of the same general form or the same as with single wires. The directivity, in which we are interested, toward a distant point on the earth's surface, from the horizontal antenna, is not changed.

[fol. 618] On the other hand, Levy has no careful provisions of that sort. The connections as shown in Fig. 1 of the patent of addition are at the corner of each of the two three wire systems, and I understand that the two three wire systems would lie in horizontal planes like the flat top which was common in antennas of the type used on board ship, and as I would gather further from the showing of Fig. 1 of the original patent.

Q. 945. As shown in Levy and in the third Carter patent, are these systems of parallel wires equivalent from the point of view of directional radiation?

A. No, I pointed out that Carter's arrangement is equivalent to a single V as far as the radiation in the horizontal plane, or measured in the horizontal plane, is concerned, but Levy's directive pattern, if there were one, would be uncertain because the phasing and the relative position of the wires are not definite.

Q. 946. Have you had prepared charts showing the directional characteristics of the net works of Levy's Fig. 1, patent of addition, at various angles?

A. No, I could not do that without knowing the phasing and the relative positions of the several wires.

Q. 947. Have you had charts prepared on the assumption of the use of single wires in place of Levy's net works?

A. Yes, I have had made up a small chart which is entitled, "Field Intensity Patterns of an Antenna Composed of Two Quarter Wave Length Wires at Various Angles."

The upper right hand corner of the chart shows the Figure 8 plot for the two quarter wave length wires at the 180 degree angle, that is to say, the di-pole arrangement corresponding to Fig. 1 of the original patent. And that, [fol. 619] of course, would be approximated if the angle were very close to 180 degrees in the case of the Fig. 1 of the patent of addition.

The figure at the upper left hand corner of this chart shows the directional pattern when the angle is reduced

to 135 degrees, and that comprises a figure which does not drop to zero in the perpendicular direction and has a somewhat reduced amplitude in the direction of the bisector.

The lower right hand corner shows the 90 degree case, which is specifically referred to in the specification of the patent of addition, and indicates a further reduction of the radiation in the direction of the bisector of the 90 degree angle, and also a symmetrical radiating pattern.

At the left of the lower part of the diagram, is the plot for the 45 degree angle, which is somewhat like that for the 135 degree angle, but still is smaller, indicating still less effective radiation.

The radii of each of these four plots in the direction of the bisector are based on unity for the 180 degree case, corresponding to the di-pole, and the assumption of a uniform loss of energy in the bisector direction as the wire is swung from 180 degrees to zero degrees.

Q. 949. Does that mean that all four diagrams on the page are drawn to the same scale, in effect?

A. Yes, to the same scale, and with the same power on that assumption, and that indicates that the best radiation is from the 180 degree case, and also the best ratio of radiation in the desired direction, to the direction perpendicular to that.

Mr. Blackmar: I offer the diagram referred to by Mr. Hogan in evidence.

(Marked Plaintiff's Exhibit 51 in evidence.)

[fol. 620] Q. 950. Does Levy teach what kind of directivity, if any, will be secured by the arrangement of his net works in accordance with Fig. 1 of his patent of addition, and as described therein?

A. No, he does not, so far as I can find.

Q. 951. Mr. Kelley was asked in Q. 479 (R. p. 361): "Will you compare the disclosure of these two French patents to Levy, that is, the original and the patent of addition, with the disclosure of the second Lindenblad patent?" And the answer was: "Again assuming that Fig. 2 of the second Lindenblad patent is for a standing wave antenna, then Fig. 1 of the Levy patent of addition is of course the same thing." Do you agree with that?

A. No, it is not the same thing.

Q. 953. Refer, please, to the Japanese patent to Takagishi:

does that patentee make clear to one skilled in the art what he proposes to do, and how he proposes to do it?

A. Yes, he proposes to use vertical antenna wires to radiate waves upward at a high angle; and he proposes to do that by staggering the ends of these vertical wires by an amount such that the angle of the stagger is equal to the desired upward angle of radiation. That is shown, for example, in Fig. 2, the upper left-hand figure of the drawings of the patent, where the ends of the wires are staggered and the direction of radiation is supposed to be along the line connecting the two ends of the wires.

Q. 954. Is there anything in the theory of this patentee that requires his wires to be more than a fraction of a wave length long?

A. No, there is not. Further, his own tests of his own invention used 40 meter waves with wires of various lengths, from 26 meters downward. These tests are described in [fol. 621] the patent itself. The longest wire that he used then would be 65 per cent. of the wave length in working out his own experiments.

Q. 955. Does this patentee depend for his supposed system upon the utilization of the principal lobes of radiation at an acute angle from his wires?

A. No, he does not.

Q. 956. With respect to each of the three antenna patents in suit, that is the first and second Lindenblad and the third Carter patent, do they depend in their principles of operation upon the principal radiation at an acute angle with the wires?

A. Yes, they do; each one of the three patents shows antennas which depend upon that type of radiation.

Q. 957. Does this Japanese patentee teach or suggest the use in his system of wires several wave lengths long or having several standing waves thereon at the operating frequencies?

A. No, so far as I can find in the text there is no such teaching, and in the illustrations, there is no wire shown that is more than a little over one wave length long. Each of Figs. 1 and 4 shows one wire with a little more than one complete wave on the wire.

Q. 958. Please take up the first Bethenod French patent, No. 596,737: what does Bethenod teach as to the length of the wires in his networks, designated 2 and 3 on Fig. 1 of the drawing?

A. There is no teaching that I can find as to the length

of the wires in either of the networks 2 and 3. Bethenod simply says that the fundamental wave length of the entire system, that is, from 2 down through the line to the generator and back up the line to 3 is lower than the trans- [fol. 622] mission wave length in general. That would mean that the whole electrical length, from one of the networks through the system and back to the other would be less than one-half wave length. There is nothing stated as to the length of any part of that complete system nor specifically as to the length of the part comprised by the networks.

—. Please tell us what you understand by the statement in the Bethenod patent No. 596,737, that "the antenna thus constituted may be operated at the harmonic."

A. That statement appears at the beginning of the third paragraph on page 1 of the translation, and "the antenna thus constituted", I understand is the system which has been described in the preceding paragraph and which I have described in my earlier answer. That system, the specification says, "may be operated at the harmonic," and of course that means that that system may be operated at a frequency which is two or three or even more times the fundamental or low frequency of the system which is referred to in the first paragraph.

Q. 961. What does that indicate as to the length of the wires in the networks 2 and 3?

A. It doesn't indicate anything with respect to their length, because there is no statement of the proportion of the total electrical length of the entire system which is in the horizontal wires.

Q. 962. Are Bethenod's networks connected to high frequency apparatus at adjacent ends or excited at adjacent ends?

A. No, each of the two networks as shown in Fig. 2 is fed centrally, and at the center the currents in each of the net works will travel in opposite directions, that is, on each side of center.

[fol. 623] Q. 963. On page 3 of the translation, Bethenod refers to obtaining directional effects either in the horizontal plane or in the vertical plane or in both planes. Does he tell you how to incline his networks in order to secure any particular kind of directivity?

A. No, he makes only a perfectly general statement that the networks may be arranged vertically or even inclined

not only with respect to the ground but also with respect to one another. That general statement covers a multitude of cases, and does not single out any one of them for any particular purpose.

Q. 964. Do you agree with Mr. Kelley that with inclined arrangements such as suggested by Bethenod, the wires of one network may all be parallel with all of the wires of the other network?

A. Yes, that would occur in several of the cases included in the general statement of inclination.

Q. 965. Do you also agree with Mr. Kelley that this is a possible arrangement, and that there are quite a few possibilities within the description of Bethenod?

A. Yes.

Q. 966. Does Bethenod state or suggest in this patent that there is under any circumstances any particular angle between the wires of the networks or between his networks that would be desirable for any purpose?

A. No, he specifies no particular angle for any purpose, and neither does he specify any particular type of inclination which would show where any particular angle would be measured.

Q. 967. Referring to the Melton article in the August, 1926, issue of Q. S. T. Magazine, as I understand the defendant's position, it is that if Melton bent over one of his long vertical wires, which he says may be done, that wire, with its [fol. 624] image in the ground, becomes equivalent to two long parallel wires fed in phase opposition. Do you agree with this?

A. No. I do not agree, because in making that comparison, Mr. Kelley suggests a purely theoretical equivalent that can never be had in short wave practice. To do it, he must assume a theoretically perfect ground which never is found, so that he may have the true image which is required for the assumption of equivalence. Beyond that, he must compare the single wire and its assumed perfect image with the two wires, assumed to be in free space, whereas, the practical case puts the two wires always above an actual ground, consequently, even if one did assume the image theory to apply, as Mr. Kelley uses it, the two wires would also have their images in the ground, so that in effect they would be equivalent to a four-wire system, and consequently would be quite different from a single wire.

Q. 970. And what is the practical difference as to directivity between a single-wire antenna over actual ground and

the two-wire antenna, such as that of the first Lindenblad patent, also over actual ground?

A. The two-wire antenna will be more than twice as directive as a single-wire antenna, assuming the best conditions for each case.

Q. 971. May I ask you what you mean by "best conditions"?

A. Best conditions as to two wires in terms of spacing and stagger and with respect to the single wire, the best direction for its particular length and so forth.

Q. 972. What about their relative height above the ground?

A. You would assume the same heights of the centers of the systems.

[fol. 625] Q. 973. Now, will you please briefly explain why there is this difference in directivity?

A. Because the radiation in the desired direction from the two wires is made to add, which gives this substantial increase in the directivity over a single wire, and then to that is added the effect of reflection from the ground beyond the antenna system, to whatever extent that may exist over the particular ground. That same effect of reflection from the ground beyond the antenna is assumed to help out the radiation from a single wire to the same extent, but to no greater extent, so that the more than doubled directivity of the two long wires still determines the ratio of improvement of the two wires over one.

Q. 974. In this Melton article, is there any mention or suggestion of utilization of the effects of an image in the operation of his antenna?

A. No, there is not.

Q. 975. In fact, is there any mention of an image?

A. I can't find any.

Q. 976. Is there any suggestion that Melton considers his single wire as equivalent of two parallel wires?

A. No.

Q. 977. Please refer to Defendant's Exhibit JJ, which is the Bruce theoretical curve of September 28, 1926. Does that teach the use of a V antenna?

A. No; if anything it teaches the use of a single tilted wire.

Q. 978. Mr. Kelley stated, referring to this diagram (R. p. 584): "Here is a definite teaching relating the electrical length of one side of a V-shaped antenna to the angle of the bisector for optimum results." Do you agree with that?

A. No, I do not. I understand and believe that at the

most this diagram teaches the inclination of a single wire [fol. 626] to the direction of arriving waves for the best signal.

Q. 979. Do you understand the theory of the derivation of this curve?

A. Yes, I understand the basis of the Bruce rule, that is, that the projection of the wire on the direction of wave arrival shall be one-half wave length less than the length of the wire itself, so that the proper phase relation in the wire will be had.

Q. 980. Is the presence of ground or of an image necessary for the derivation of the Bruce rule, or rule of thumb, as Mr. Kelley has expressed it?

A. No, it is not necessary in any sense. The same rule would apply to a single wire in free space.

Q. 981. If such tilted wire were used in practice, would it be equivalent to a V antenna?

A. No.

Q. 982. Why not?

A. Because there is nothing to correspond to the other wire of the V. Mr. Kelley, in discussing one aspect of this, assumed the wire to be set up over theoretically perfect ground, and thereby found and assumed true image of the tilted wire. Then he took that image to be the second wire of a V. But that can never occur in short-wave practice, as I have explained, because there is no such thing as the perfect ground which he had to assume.

Q. 983. Mr. Bruce was asked, Q. 45 (R. p. 507), with respect to this sketch as follows: "On this sketch it is annotated that the ground is shown in the conventional character of lines as well as the word 'ground'. Will you state whether or not in making that sketch you considered actual ground or perfect ground?" And his answer to that question was as follows: "In a sketch of this type the important thing is the relation of the wire with the direction of the [fol. 627] wave. However, perfect ground is intended in this case to fit that assumption."

Do you consider what you have just stated to be consistent or inconsistent with Mr. Bruce's testimony?

A. What I have spoken of is a different effect of perfect ground and a different assumption, but Mr. Bruce is correct in saying that the assumption of perfect ground would correspond to the horizontal wave direction which he showed, and therefore the drawing of his line marked "ground" would give him a line at the base or left-hand end of the antenna wire upon which to draw his projection.

Q. 985. Now, to assume a theoretical case of perfect ground, is there any difference between a single tilted wire above the ground and a V antenna likewise above the ground?

A. Yes.

Q. 986. What is that difference?

A. The V antenna under those assumptions would have a complete V image below it, and thus form a four-wire double V system, including the image assumption.

Q. 987. Now, in practice, referring again to Defendant's Exhibit JJ, is the direction from which short waves are received horizontal, as indicated in this sketch?

A. No, in practice they have a wave front corresponding to arrival at angles from 10 degrees to as much as 20 degrees or more above the horizontal.

Q. 988. Now, applying Bruce's rule for optimum angle between the wire and assumed wave direction to the practical case of a wave coming in at an angle to the horizontal, would the angle of Bruce's wire to the ground, as shown in this Defendant's Exhibit JJ, be changed?

A. Yes. If we should assume that the wave direction were 10 or 20 degrees downward toward the earth, then following [fol. 628] Bruce's rule, which says that the projection of the wire on the direction of arrival of the waves is to be one-half wave length less than the length of the wire, the wire would have to be tilted so that its upper end was higher in the air, in other words, so that it made a greater angle with the ground, the angle of the wire from that shown for horizontal arrival being increased by the same angle of wave arrival direction, namely, the angle between the arrival of waves on the ground plane; in other words, following the Bruce rule, the wire would make a larger angle with the ground. In other words, it would be nearer the perpendicular.

Q. 991. What effect would that have as to the angle between the wire and its image, if there were an image?

A. Assuming that there were an image and that the wire were tilted up to a more nearly perpendicular position, the assumed image would tilt down correspondingly and the angle between the wire and the image would be correspondingly increased, the total angle being double the change made in the one wire.

Q. 992. If, then, we assume that there is an image and that therefore the Bruce wire represents a V antenna, how would

the angle between the legs of this supposed V and its bisector compare with the angle recommended by Carter in his third patent?

A. On those several assumptions the angle would be increased, as I have said. If the change in the wave direction above ground were 10 degrees, the Bruce angle would be raised by 10 degrees for each point corresponding to the length of the wire.

Q. 993. Will you please explain that with reference to Defendant's Exhibit W?

[fol. 629] A. Yes; it would mean under those assumptions that the curve marked Bruce angle would be raised at all points by about ten degrees, if that were the correct direction of wave arrival with respect to the ground, and consequently would proceed through the plot of Fig. 12 at a distance several times farther from the Carter curve than is indicated here by the curve marked "Bruce angle".

Q. 995. Please refer to the Bethenod French patent No. 625,293. As I understood the testimony of Mr. Kelley with respect to this patent, he stated in effect that the structure shown therein represented to one skilled in the art a V antenna, considering the image; do you agree?

A. No, I do not. I have already explained how the necessity of assuming a true image from a perfect ground is not a practical case and cannot be attained. In this instance there is another difference in that the wire from B to C, which is supposed to be the radiating part of the Bethenod antenna, is at a considerable vertical distance from ground at the point A, and consequently, even assuming that there could be an image of the radiating part in perfect ground, it would be far below the ground, as far below as the elevation from A to B, and consequently would not constitute a V.

Q. 996. What is your understanding of the teachings of this patent with respect to the use of long wires?

A. The only statement I could find which bore on that is at the top of page 2 of the translation, which says that the length BC, that is, the radiating portion to which I referred, is preferably chosen to be a whole number of half waves. That, of course, has the meaning that the suggestion is met whether the wire is one half wave length, two half wave [fol. 630] lengths or one wave length long, and so forth, by any integral number of half waves.

There is no advantage stated for making the wire longer than half a wave length, and there is a very good reason for following the half-wave requirement that is stated, namely, because the voltage loop comes at the end B and consequently at the top of the section AB, so that the open end of the radiation-cancelling wire F may have a voltage loop and operate to neutralize the radiation from the vertical AB, which is one of the objects, if not the object, of the Bethenod arrangement. That is done just as effectively with the wire length from B to C of one half wave length or of one wave length as it is with a longer wire.

Of course, the drawing indicates that the length BC is not very long, but that is a mere indication.

Q. 997. Now, Mr. Kelley, in answer to Q. 463 (R. p. 352), stated that this patent relates to a short wave directional antenna. Do you agree with that statement?

A. No, I think he must ~~have~~ misunderstood the last paragraph of the specification just before the résumé. There it states that several antenna arrangements of the same kind, suitably positioned or orientated in reference to one another, may be combined in one and the same station with a view of insuring directional properties. That is the only reference I found as to directional operation, and that teaches a combination of several of the simple antennas into an array to produce directive radiation.

It does not teach that the single antenna of Bethenod's type is directional.

Q. 998. Is there in this patent any mention or suggestion of the utilization of the effect of an image in the operation of its antenna?

[fol. 631] A. No, I could find no suggestion of that. In fact, I found no mention of an image.

Q. 1000. Is there any suggestion that Bethenod considered his single wire as the equivalent of two wires?

A. No, I found no suggestion of that, either.

Q. 1001. Please refer to the Abraham 1898 and 1901 articles. Did Abraham in either of those articles, suggest any practical application of his mathematical analysis of the radiation patterns of a conductor?

A. No, I found no suggestion of a practical application.

Q. 1003. Did he suggest that these analyses might be useful to obtain directive radiation?

A. Not at all.

Q. 1004. Did he consider the radiation pattern which might result from combining two or more conductors?

A. No.

Q. 1005. At the time that Abraham made these analyses was there available in the art any source of high frequency oscillations which could be used to excite a wire or conductor at a single harmonic frequency?

A. No, the only source available was the spark excitor, which set up simultaneously the fundamental vibration of the conductor and with it a number of harmonics; the fundamental vibration in general being much stronger than any of the harmonics.

Q. 1006. What do you understand that Abraham was seeking to explain in these articles?

A. He was seeking to explain the fact that a spark-excited radiating conductor could vibrate simultaneously at its fundamental frequency and at a number of harmonic or nearly harmonic frequencies. That is to say, that all of these currents of different frequencies could co-exist in such an oscil-
[fol. 632] lator. Having shown that, he investigated the radiation from a wire or an assumed conductor, carrying all of those frequencies simultaneously, and he analyzed the total radiation from that wire into the part of that total radiation that might be contributed by each of the several simultaneously-excited frequencies in the conductor.

Q. 1007. Mr. Hogan, have you had charts prepared showing the situation with respect to radiation in the horizontal and vertical planes of the bisector in free space of a V antenna eight wave lengths long, with an included angle, I think, of 12 degrees?

A. Yes, I have two graphs which show the power distribution of the radiation both in a horizontal plane and in a vertical plane along the bi-sector of a pair of horizontal wires each eight wave lengths long and arranged with an included angle of 12 degrees. This corresponds approximately to the range given in the second Lindenblad patent which said a wire length of from five to ten wave lengths, and with spacing at the end of one-fifth of the wire length. So that these patterns show the theoretical free space radiation from an antenna of that character arranged as a horizontal V.

Q. 1008. How does that angle compare with the angle recommended for wires of that length in the third Carter patent?

A. It is much less, that is to say, the angles shown in these plots are much less.

To continue: The chart showing the power distribution in the horizontal plane shows a power proportional to a little over six and a half in the geometrical line of the bisector, and a substantially greater power of something over eleven [fol. 633] in the general direction of the bisector, but inclined at something like 20 degrees either side of the geometric bisector line. This is the fanwise radiation of which I spoke.

The vertical plane chart shows the concentration of the radiated power into the general plane of the wires, that is around the plane of the wires, and with the large lobes extending somewhat, both upwardly and downwardly.

Mr. Blackmar: I offer in evidence as one exhibit the two charts referred to by the witness in his immediately preceding answers.

(Marked Plaintiff's Exhibit 52 in evidence.)

Q. 1010. In describing the chart covering power distribution in the vertical plane of Plaintiff's Exhibit 52, did you state what it shows with respect to radiation along the bisector in that plane?

A. I think I said it was the vertical plane of the bisector.

Q. 1011. Please look at Defendant's Exhibit FF, which I understand purports to show radiation in the vertical plane of wires four wave lengths long with the angle of 11.4 degrees, as stated thereon. Please consider that with respect to the radiation in the direction of the axis of the system.

A. It shows that in the vertical plane for this four wave V, the radiation is concentrated around the plane of the wires, that is to say vertically, in the direction in which the wires extend. It is generally similar to the vertical plot of Exhibit 52, except as to proportions, and as to the fact that the two ends on the bisector are pointed and go out further than in the case of Exhibit 52, go out further in proportion.

[fol. 634] Q. 1013. In connection with Plaintiff's Exhibit 52, have you had prepared charts showing the comparative gain along the bisector as compared to a di-pole as a standard; that is, the comparative gain of wires eight wave lengths long with an angle between them of 12 degrees?

A. Yes, I have had such charts prepared. The first one to consider is the power distribution in a horizontal plane of a horizontal di-pole which is marked on the chart that

way. That shows by the simple figure 8 in the center of the chart, the distribution measured in the horizontal plane around the di-pole or half wave wire, which is assumed to lie in the plane of the paper and from the top to the bottom of the sheet. The radius of the lobes on each side of the wire is unity, because we are taking that amount as standard radiation, that is, the radiation in the desired direction from the horizontal di-pole.

The second chart is the power distribution in a vertical plane perpendicular to the wires of this same horizontal di-pole, and that shows a simple circle with the radius of unity. It shows the result with the di-pole as a wire extending perpendicular to the paper, and the paper being held in the perpendicular plane; therefore, the radiation is symmetrical that way and of unit value.

Now, the next sheet is the power distribution from the eight-wave-length wire, V, having an included angle of 12 degrees, plotted on a scale which uses the same power input as in the case of a di-pole, so that the extent of the radiation indicated gives a direct comparison of the relative power in the various directions shown, as between this eight-wave-length 12-degree V and the di-pole. It shows that in [fol. 635] the horizontal plane the radiation along the geometrical axis of this system, the actual gain is something over twice that of the di-pole and that in the general direction of the V antenna the radiation is about 3.7 times in power that of the di-pole.

The fourth curve is the power distribution in the vertical plane for this same V antenna, and, of course, since it is taken in the plane of the axis, the measurement—the maximum radius—of the plot coincides with that for the direction along the zero-degree line in the third chart to which I referred.

These charts represent radiation patterns in free space.

Q. 1016. Have you also had prepared charts for wires of the same length, namely, eight wave lengths, but placed at an angle in accordance with the recommendations of the third Carter patent, and plotted on the same scale as the four charts to which you have just referred?

A. Yes. I have here the vertical and horizontal power distribution for eight-wave-length wires in a V, having an included angle of 35 degrees. The power input is assumed to be the same as for the di-pole shown in the other curves to which I have just referred, and the scale of the diagrams

is the same, so that for this particular case, the power gain in any direction in either the vertical or horizontal plane of the bisector is indicated by the numerical scale.

This shows that in both the horizontal plane and in the vertical plane the principal radiation is concentrated not merely in the general direction of the bisector, but along the bisector line. Also, that the amplitude, the power [fol. 636] radiated in the direction of maximum radiation is much greater than in the case of either the di-pole or the 12-degree V antenna.

The ratio along the exact line of the bisector is given as 10 in the one chart for the vertical plane and I have just observed, as 10.2 along the bisector line for the power distribution in the horizontal plane. I think the 10.2 figure is correct for both charts, and that they should be corrected to that extent; otherwise I think they are right.

Mr. Blackmar: I offer in evidence the six charts last referred to by the witness showing comparative power distribution in horizontal and vertical planes of a di-pole and of a V-shaped antenna eight wave lengths long with an included angle of 12 degrees, and of a V antenna with wires eight wave lengths long with the angle recommended in the third Carter patent.

(Marked Plaintiff's Exhibit 53 in evidence.)

Q. 1017. What is the power gain of a pair of eight-wave-length parallel wires with the best stagger and spacing in the plane of the wires and direction of the principal lobe?

A. That I understand is 8.2 times the power that would be received from the equivalently-excited di-pole.

Q. 1018. And what is the power gain for the same pair of wires placed in V formation utilizing the angle recommended in the Carter patent, considering radiation along the bisector of the plane of the wires in free space?

A. That figures out as 10.2, and represents about a 25 per [fol. 637] cent. increase over the figure I have just given for the parallel wires.

Q. 1019. Have you had charts prepared comparing two four-wire systems, each of the wires in each case being eight wave lengths long, in one case utilizing the arrangement of the first Lindenblad patent with the best stagger and spacing, and in the other case utilizing the arrangement of the third Carter patent with the angle recommended by him for wires of that length?

A. Yes. I have here four charts which may be considered in pairs. The first shows the power distribution in a horizontal plane of four horizontal parallel wires each eight wave lengths long spaced and staggered for maximum addition and cancellation. That is shown in terms of power for these wires in free space with the angles drawn in reference to the wire direction. With that may be considered also the power distribution in the vertical plane of the beam of these same wires.

This second chart differs from those which I have already used because of its reference to parallel wires, in that it is taken in the plane of the beam and not in the plane of the axis of the wire system. The gain for this system, that is, the power measurement, is about 16.4, as shown in the curve.

The other pair of curves is plotted for a double four-wire V antenna, each of the V's being horizontal and in the same plane, the wires being eight wave lengths long, as in the case of the parallel horizontal wires, but being set up with the 35-degree angle recommended for that wave length and wire length in the second Carter patent. The V's are spaced [fol. 638] and phased in quadrature. In other words, this corresponds generally to defendant's antenna No. 8 which we have discussed and of which the model, Exhibit 29, was a representation. This shows, in the horizontal plane, the narrow main beam giving a power gain of something over 20,—20.4, I think,—and in the vertical plane a somewhat wider lobe of radiation, but nevertheless principal radiation occurring in one direction and having, of course, the same amplitude of 20.4. That value of 20.4 may be compared with the value of about 16 which was had when the four parallel wires were used. The difference is due to the fact that when best cancellation and addition of the main radiation is had with the four parallel wires, the relation in the rest of space where the extraneous lobes exist is not as favorable for producing the directivity one desires as when one uses a V of the Carter patent and cancels the opposite lobes on the two sides of the wire, and of course, a larger part of the stray radiation in the other directions. That better effect of the case of the V is reflected in the increased gain along the bisector of the beam line.

One of these is marked "Wires in free space", and the other should have been so marked, because they all refer to that.

Mr. Blackmar: I offer the four charts referred to by the witness in respect to power distribution of four-wire antennas in evidence.

(Marked Plaintiff's Exhibit 54 in evidence.)

Q. 1020. In the course of the testimony on behalf of the defendant, it was stated, as I understand it, that the de-[fol. 639] fendant, by utilizing a smaller angle than the angle recommended in the Carter patent, derived some gain in actual direction of propagation of the waves. I hand you Plaintiff's Exhibits 37, 38, 39 and 40 for identification, and I ask you to explain what they show in that respect; this is with respect to antenna No. 2 rebuilt, as I understand it.

A. These curves correspond to the four plots that the defendant introduced with respect to antenna No. 8, and I think antenna No. 2, originally, but these correspond to antenna No. 2 as it was rebuilt. They show a power distribution in the vertical plane for the 8.14-wave-length wires having included angles in one case of 40 degrees, as used, and larger than recommended by Carter, and in the other case of 34.66 degrees, which is the angle given in the Carter patent as preferred. The results are plotted for each angle, both in free space and over perfect ground.

The graphs show that with the preferred angle the radiation in free space would be about 9.6 in power for the preferred Carter angle, and about 8 for the 40-degree angle actually used.

They also show that over perfect ground, where the addition of energy reflected upward from the ground beyond the antenna comes into play, the power distribution would be 18.3 in the direction approximately 9 degrees upward from the ground with the angle of 40 degrees between the wires as actually used, but would be increased from 18.3 to about 23.2 if the angle of 40 degrees actually used had been reduced to a smaller angle of 34.66 degrees, as recommended in the Carter patent as the preferred value for the V.

[fol. 640] Mr. Blackmar: I offer in evidence these exhibits, namely Plaintiff's Exhibits 37, 38, 39 and 40 for identification.

(Marked Plaintiff's Exhibits 37, 38, 39 and 40 in evidence.)

Q. 1021. Please refer to Defendant's Exhibits Y and Z. Do these diagrams indicate in your opinion anything as to

comparative directivity when a V antenna is composed of wires of seven and three-quarter wave lengths long as compared to a V antenna having wires eight wave lengths long, each utilizing the angle recommended in the third Carter patent for wires of those lengths?

A. These are radiation plots intended to show part of the pattern around a single wire. In the one case, seven and three-quarter wave lengths long, and in the other case eight wave lengths long. They do not show the radiation of a V made of either one of those wires as its side element, but so far as one can judge from the graph here, the directivity of the two V's would seem to be about the same. There is no striking difference either as to angle or extent of the lobes in the two cases, although the length of the eight wave length lobe is slightly over 30, whereas that for the 7¾ is slightly under 30. Unless the entire pattern for the V's were computed in the two cases, and even then until it had been checked by measurements, one could not give a positive answer, but I can say that the indications are there would be no great difference between the two.

Cross-examination.

By Mr. Darby:

X Q. 1173. Mr. Hogan, I call your attention to the third and fourth sheets of Plaintiff's Exhibit 54, which show [~~fol. 641~~] the power distribution in vertical plane of the beam, four horizontal parallel wires, each eight wave lengths long spaced and staggered for maximum addition and cancellation of wires in free space. Was the spacing assumed in making these charts determined in the manner taught by Fig. 4 of the first Lindenblad patent?

A. I understand that it was determined as to the stagger angle in accordance with Fig. 4, but not as to the spacing between the wires.

X Q. 1174. Now I understand that a half wave di-pole will give a beam of radiation, a principal beam of radiation along some particular direction. If I placed a second half wave di-pole fed in phase there would be a beam of principal radiation from those two that would be about twice the power of the single di-pole, is that right?

A. Well, of course, not a beam for a di-pole but a doughnut pattern, but the last part of your question would be right, it would be broadside when they are fed in phase.

X Q. 1175. And there would be a power gain of about two to one?

A. Something like that.

X Q. 1176. If I place a wire eight wave lengths long to use as an antenna, that is equivalent to sixteen half wave di-poles placed end to end, is that right?

A. Well, there are sixteen half wave sections on the wire, but they are fed alternately as to phase in the long wire.

X Q. 1177. And if I made that into a V, then there would be sixteen in each wire or a total of thirty-two?

A. So far as the total number of half wave sections is concerned, and without regard to their relative phases.

X Q. 1178. Referring to Plaintiff's Exhibit 53, I understand that the first sheet, power distribution in horizontal plane of horizontal di-pole, that is for a half wave di-pole, [fol. 642] is it not?

A. That is right.

X Q. 1179. And the third sheet, which is labeled "Power distribution in horizontal plane, horizontal wires eight wave lengths long, included angle 12 degrees, power input same as for di-pole," the power angle in this last instance in the direction indicated by the zero line is approximately twice that indicated along the same zero line as illustrated in the first sheet of power distribution in horizontal plane of horizontal di-pole, is that correct?

A. Yes, about 2.2.

X Q. 1180. And I gather from one of your previous answers this morning that you would obtain about that same degree of power gain if you used two half wave di-poles?

A. In that particular direction.

X Q. 1181. In that particular direction?

A. But you would have a totally different radiation pattern.

X Q. 1182. In that particular direction you would have approximately the same gain?

A. That is about right.

Redirect examination.

By Mr. Blackmar:

R. D. Q. 1230. There was reference this morning to a wire, an antenna wire eight wave lengths long, and there was, as I understood it, a suggestion that it might have some equivalence or some relationship to 16 di-poles. With an antenna utilizing a system, for example, of 16 di-poles,

what would the feeding arrangement of such an antenna be or have to be?

A. A typical arrangement of that sort would have 16 di-poles independently supported, perhaps horizontally, spaced with regard to each other, and each fed at the [fol. 643] center with a transmission line connection. In other words, there would be a multiplicity of divided transmission lines feeding each of the 16 di-poles.

R. D. Q. 1231. How does that compare as to simplicity with building two wires, each eight wave lengths long?

A. The di-pole case is obviously much more complicated.

R. D. Q. 1232. Have there been types of antennas referred to in this case, which are instances of multiple di-pole arrangements?

A. Yes.

R. D. Q. 1233. What are they?

A. Those used at the Sayville Station, which were described by Mr. Hansell were the only practical cases I recall. There may have been some reference in the publications to them.

R. D. Q. 1234. Are there other types of antennas which utilize half wave radiators, possibly not referred to as di-poles?

A. Oh, yes, there are the curtain types of antennas, for example, the model A antenna, and the Marconi beam, in which the effect is generally that of a series or multiplicity of di-poles.

Mr. Darby: That is all.

Mr. Brown: I offer in evidence a certified copy of Bruce's application, Serial No. 513,063 for improvement of horizontal V antenna, which is the application filed in the United States, and upon which the British patent was filed under the convention.

Mr. Darby: If your Honor pleases, I make the same objection to this as to the others, as to its relevancy and materiality.

(Marked Plaintiff's Exhibit No. 55 in evidence.)

[fol. 644] Mr. Blackmar: In the course of the progress through the Patent Office of the application which resulted in the first Lindenblad patent in suit, two British patents were cited, namely, British patent No. 233, 346 and British patent No. 251,638. I offer those two patents in evidence.

(Marked Plaintiff's Exhibits Nos. 57 and 58, respectively, in evidence.)

[fol. 645] IN UNITED STATES DISTRICT COURT, EASTERN DISTRICT OF NEW YORK

[Title omitted]

STIPULATION AS TO NARRATIVE FORM OF EVIDENCE

It is Hereby Stipulated and Agreed, by and between the Solicitors for the respective parties to the above entitled suit, subject to the approval of this Court, that the annexed statement of evidence is true, complete, and properly prepared and may be treated and considered as a record of the proceedings at the trial of said cause in making up the transcript of record on the appeal by the plaintiff; and that the testimony in this stipulated statement of evidence (except the experts' testimony) is stated in narrative form except where it was desired to retain the exact words of the witness; and it is

Further Stipulated and Agreed that either party may refer to the original transcript of testimony taken at the trial for correction of errors in the printed record.

Dated, New York, N. Y., October 6th, 1937.

Sheffield & Betts, Solicitors for Plaintiff. Darby & Darby, Solicitors for Defendant.

[fol. 646] IN UNITED STATES DISTRICT COURT, EASTERN DISTRICT OF NEW YORK

[Title omitted]

ORDER APPROVING NARRATIVE STATEMENT OF EVIDENCE

Now, on this 8th day of October, 1937, on reading and considering the annexed stipulation of the Solicitors for the respective parties, it is hereby

Ordered that the annexed narrative statement of evidence in the form provided by said stipulation be and it hereby is approved as true, complete and properly prepared; and it is

Further Ordered that the same be filed as a statement of the evidence to be included in the record on appeal.

Marcus B. Campbell, U. S. D. J.